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COMPARATIVE PHYSICAL CONDITION OF FOUR DEER HERDS IN NEW YORK ACCORDING TO SEVERAL INDICES[1]

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ABSTRACT

Approximately 1,300 deer, killed by hunters during January post-season deer hunts, were processed in such a manner that several physical indices were checked simultaneously: age composition, live and dressed weights, hind foot length, girth, eye lens weight, kidney weight-kidney fat weight index, antler size and reproductive rate. Of the four deer herds involved, two were rated as poor, based on physical condition, and two as good to excellent. Dressed weight was used as a base in making correlations with other indices. Dressed weight, reproductive rate, eye lens weight and antler size in association with age composition proved to be the best indices for measuring physical condition. Girth measurement needs further investigation as an alternative index to dressed weight. The kidney weight-kidney fat weight index apparently has too many variables and inconsistencies to be used except in a very gross manner. Hind foot data also had inconsistencies which limit their usefulness.

Several indices are used by big game managers to evaluate the physical condition of a deer herd and the range that produced those deer. Some of these indices are more sensitive than others. Some tend to be applicable to measuring long-term range conditions, while others may only apply to conditions of short duration. Some are more easily obtained than others. No one index can give all the answers. Therefore, several indices are usually used. Rarely is it possible to collect large samples of data at any one time whereby several indices can be checked simultaneously.

In January of 1965, 1966 and 1967 the State Conservation Department conducted post-season deer hunts in local areas where a reduction in the abundance of deer was needed. Participating hunters were required to bring their deer "in the round" to a central point where Department personnel recorded biological data and field dressed the deer.

The post-season hunts in 1965 were conducted in three areas: near Lordville in Delaware County, near Ripley in Chautauqua County and

[1] A contribution of Federal Aid in Fish and Wildlife Restoration Project W-89-R.

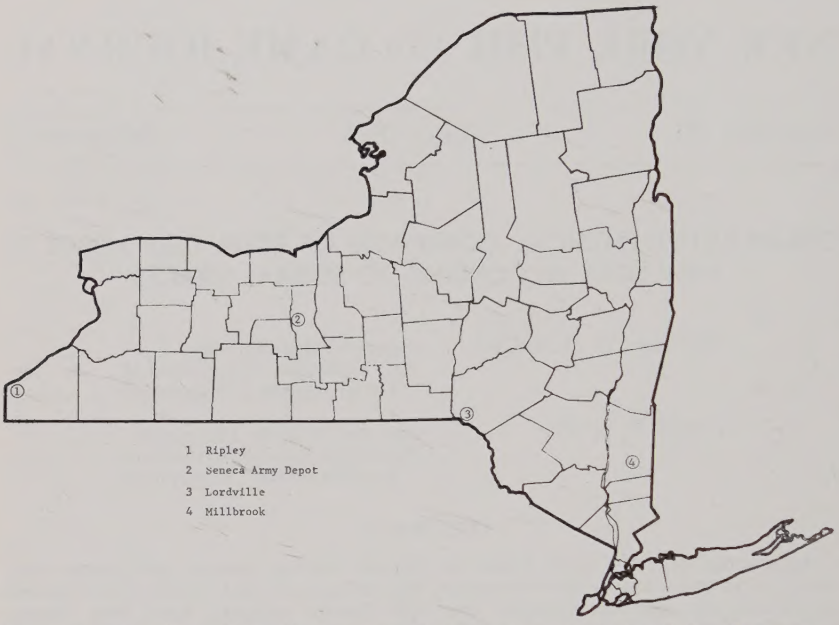

Figure 1. Location of the four areas where data were obtained for deer taken during post-season hunts.

at the Seneca Army Depot in Seneca County (Figure 1). The Lordville hunt was designed to reduce the size of a wintering deer herd that had suffered starvation losses of more than 50 animals per square mile (Hesselton, 1963). The Ripley hunt was designed to reduce a wintering herd of some 1,500 to 2,000 deer that concentrated in an agricultural area of approximately 25 square miles along the shore of Lake Erie and caused severe damage to crops, especially fruit trees. Another reason for reducing the size of this herd was that three major highways (including the Thruway) plus a mainline railroad traversed the area. Hundreds of deer were being killed each year by trains and motor vehicle, and driving conditions were hazardous. The post-season hunt at the Seneca Army Depot was part of continuing research to obtain life-equation data, among other things, from a semi-confined deer herd (Hesselton, 1965).

Additional data were collected at Lordville during January 1966, and at the Seneca Army Depot and the Millbrook area in Dutchess County in January 1967. Deer were harvested at Millbrook because of excessive agricultural damage.

The objectives of this study were:

1. To compare the physical condition of several deer herds, in different parts of the State, using several physical indices as indirect measures of relative range condition.

2. To gain some knowledge of the reliability and relative applicability of the physical indices used.

PROCEDURE

Several techniques were used to collect the data.

1. Age. The age of each deer was determined by the tooth-wear technique (Severinghaus, 1949). This is accurate for assigning age to deer up to 1 year and 7 months old, but, since the collection of these data, the tooth-sectioning technique has proved to be more accurate for older deer (Sauer, 1971). She found that ages assigned by tooth wear were significantly different from those assigned by tooth sections for deer 2 years old and older on poor range in Delaware and Ulster Counties. They were not significantly different for deer from good range in Ontario County. In light of these findings, the age-physical index relationships presented in this paper for deer older than fawns should be considered tentative until they have been confirmed by further work using tooth sections to assign age.
2. Weight. Live and dressed weights, in pounds, were taken on standard platform scales.
3. Hind foot length. Hind foot measurements, to the nearest centimeter, were made with a steel tape measure. The left hind foot was measured in all instances. The measurements were taken on the outside of the leg from the tip of the heel or hock (tuber calcis) to the tip of the hoof, with that part of the leg completely extended.
4. Girth. Girth was measured, to the nearest millimeter, before the animal was dressed, with a steel tape drawn as tightly as possible around the chest directly behind the scapulae.
5. Eye lens weight. The left eye was removed, labelled and preserved in a solution of 10 per cent formalin for approximately 7 months. Lenses were removed, oven dried at 120° C. for 7 days, air cooled for 15 minutes and weighed to the nearest 0.1 milligram on a Mettler Model B direct-reading scale as described by Friend and Severinghaus (1967).
6. Kidney fat index. A ratio of kidney fat to kidney weight without fat was determined according to the technique described by Riney (1955). Figure 2 indicates how the kidney fat was trimmed to standardize the measurement. Both kidneys were used. Kidneys with fat were weighed to the nearest gram on a standard spring scale. Then the kidneys were re-weighed after all fat had been removed.

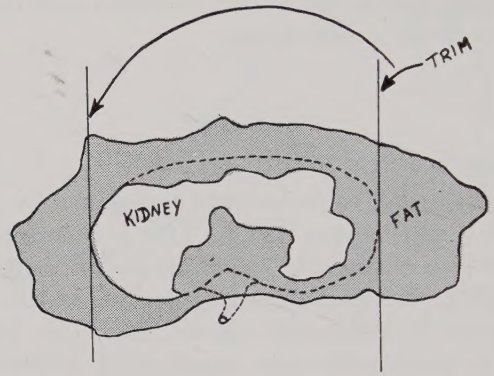

Figure 2. Technique employed for trimming kidney fat.

7. Antler size. Unfortunately, the hunts were held at such late dates that most of the male deer had shed their antlers, except for those at the Seneca Army Depot which for some unknown reason retained their antlers until late January in both years. For purposes of comparison, antler data for fall-killed deer in the Ripley, Lordville and Millbrook areas were used. Average antler beam diameters taken 1 inch above the "burr" and number of points 1 inch long from the edge of the beam were recorded — see definitions in Eabry (1970).
8. Reproductive rates. Entire reproductive tracts were collected from virtually all female deer. Tracts were placed in individual plastic bags, labelled and frozen. Later, they were examined, the number of embryos per doe (including both pregnant and non-pregnant females) was recorded, and the ovaries were preserved in 10 per cent formalin for further examination.

Several statistical tests were employed in analyzing the data. The numbers of animals harvested differed for each of the post-season hunts, and the physical indices recorded varied between hunts. Wherever possible, mean values for a given index were compared for all hunts by an analysis of variance (after comparing variances with Bartletts test[2] for homogeneity) for the following sex and age groups: female fawns, female yearlings, females 2½ years old, females 3½ years old and older, and male fawns. Tukey's "D" value[2] was then computed to determine or isolate the group or groups that caused a significant ($P = 0.05$) difference between means. It was assumed that by 3½ years females had essentially completed their growth and that differences between areas in age composition among deer 3½ years old and

[2] From Snedecor and Cochran (1967): Bartlett's test, pp. 331-337; Tukey's "D" value, pp. 296-298.

older would not affect the means of pyhsical indices. Males older than fawns could not be compared because, except at the Seneca Army Depot, the availability of older males was reduced by hunting during the regular big game season. Differences in reproductive rates were tested by a chi-square comparison of pregnant females and the number of embryos produced.

FINDINGS

Findings for each of these indices are presented in the same order that they have been described.

AGE COMPOSITION

Table 1 and Figure 3 show the differences in age composition on the four areas for deer 1½ years old and older. The herd at the Seneca

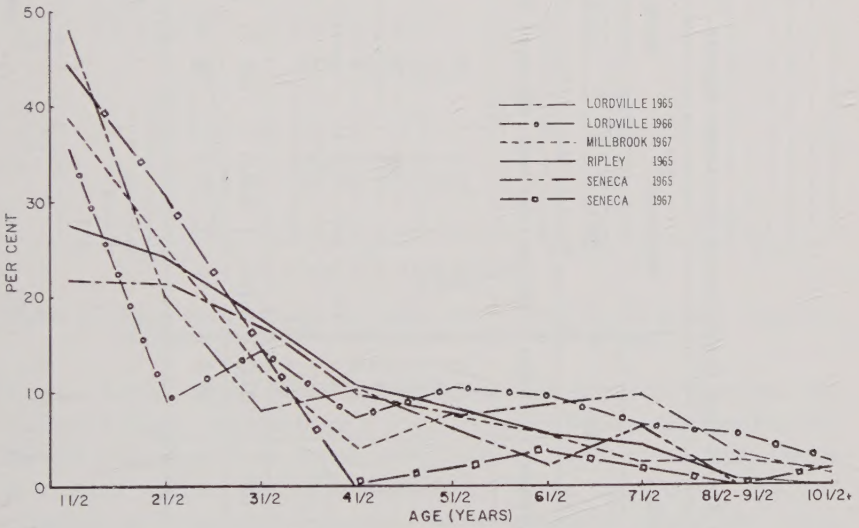

Figure 3. Age composition among adult female deer.

Army Depot was obviously the youngest and most heavily harvested. That at Lordville was at the other extreme with a low recruitment and a high proportion of older deer. For Ripley and Millbrook, the age compositions indicate situations intermediate between the other two.

WEIGHT

Round weights and dressed weights showed similar trends (Table 2). Dressed weights are compared graphically for females in Figure 4. Female fawns from Lordville and Millbrook weighed approximately the same and were significantly lighter than those from Ripley and the

TABLE 1. AGE COMPOSITION FOR ADULT FEMALE DEER TAKEN DURING POST-SEASON HUNTS*

Age (years)	Lordville				Millbrook		Ripley		Seneca Army Depot			
	1965		1966		1967		1965		1965		1967	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
1½	49	21.8	45	35.4	68	38.8	39	27.7	24	48.0	23	44.3
2½	48	21.3	12	9.5	44	25.2	34	24.1	10	20.0	16	30.7
3½	38	16.9	18	14.2	22	12.6	25	17.7	4	8.0	8	15.4
4½	22	9.8	9	7.1	7	4.0	15	10.6	5	10.0	..	..
5½	17	7.6	13	10.2	13	7.4	12	8.5	3	6.0	1	1.9
6½	19	8.4	12	9.4	9	5.1	9	6.4	1	2.0	2	3.9
7½	22	9.8	8	6.3	4	2.3	6	4.3	3	6.0	1	1.9
8½–9½	7	3.1	7	5.5	5	2.9	1	0.7	..	..	..	..
10½+	3	1.3	3	2.4	3	1.7	..	..	..	..	1	1.9
Total	225	100.0	127	100.0	175	100.0	141	100.0	50	100.0	52	100.0
5½+	68	30.2	43	33.8	34	19.4	28	19.9	7	14.0	5	9.6

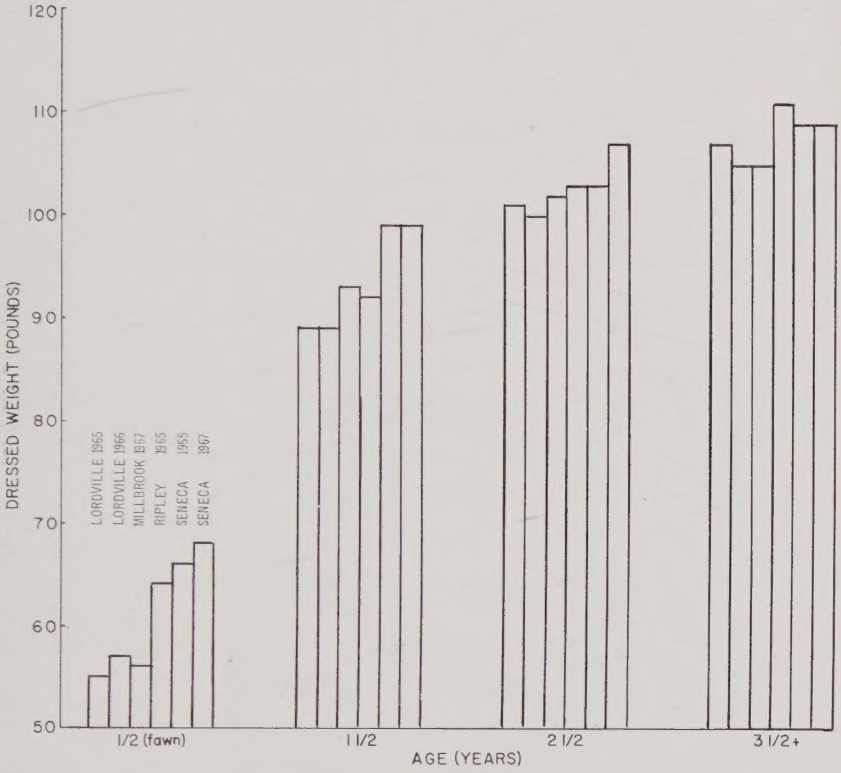

Figure 4. Mean dressed weight for female deer of different age groups. (Sequence of bars as labeled for fawns is the same for all groups)

Seneca Army Depot. Male fawns showed the same relationships. By 1½ years of age, females from the Seneca Army Depot were significantly heavier than those from Ripley and Lordville. By 2½ years, differences in dressed weights between areas ceased to be significant. The correlations and regression equations between dressed weight and other physical indices are given in Table 3.

Round weights are compared graphically for females in Figure 5. They were not recorded at Lordville in 1966 or at the Seneca Army Depot in 1965. Female fawns from the Seneca Army Depot were significantly heavier than fawns from any other area. Female fawns from Ripley were significantly heavier than fawns from either Lordville or Millbrook. Weights of male fawns did not differ significantly between Ripley and the Seneca Army Depot, but males from both the Seneca Army Depot and Ripley were significantly heavier than those from Lordville and Millbrook. At 1½ years, females from the Seneca Army Depot were still significantly heavier than deer of the same age from the other areas. There were no significant differences among the

TABLE 2. COMPARISON OF MEAN DRESSED AND ROUND WEIGHTS (IN POUNDS) FOR DEER OF DIFFERENT AGES TAKEN DURING POST-SEASON HUNTS*

Sex and locality	Fawn			1½ years			2½ years			3½+ years		
	Number	Mean weight	Standard error	Number	Mean weight	Standard error	Number	Mean weight	Standard error	Number	Mean weight	Standard error
Dressed weight												
Female												
Lordville (1965)	75	55	0.8	35	89	1.8	34	101	1.6	102	107	1.0
Lordville (1966)	38	57	1.1	30	89	1.5	10	100	3.0	44	105	1.4
Millbrook (1967)	62	56	0.8	67	93	1.3	44	102	1.7	63	105	1.4
Ripley (1965)	38	64	1.2	29	92	1.7	24	103	1.9	54	111	1.6
Seneca Army Depot (1965)	22	66	1.7	19	99	1.9	10	103	3.0	14	109	3.7
Seneca Army Depot (1967)	20	68	1.7	23	99	1.6	16	107	1.8	12	109	2.2
Tukey's "D" value§		5			7			n.s.			n.s.	
Male												
Lordville (1965)	116	58	0.8	7	90	7.4	..	..	..	..	..	..
Lordville (1966)	72	63	0.9	8	93	4.5	..	..	..	..	..	..
Millbrook (1967)	58	60	1.1	6	92	2.9	..	..	..	..	..	..
Ripley (1965)	57	71	1.0	9	109	4.5	..	..	..	..	..	..
Seneca Army Depot (1965)	21	74	2.0	24	110	2.1	..	..	..	..	..	..
Seneca Army Depot (1967)	27	72	1.1	31	115	1.6	..	..	..	..	..	..
Tukey's "D" value§		5			..			..			..	

	Round weight											
Female												
Lordville (1965)	76	72	1.0	36	116	2.3	37	131	2.1	106	141	1.2
Millbrook (1967)	62	72	1.1	67	118	1.6	44	129	2.0	63	135	1.5
Ripley (1965)	36	82	1.6	30	118	2.1	24	132	2.4	54	141	1.8
Seneca Army Depot (1967)	20	87	1.6	23	127	2.0	16	136	2.3	12	141	2.1
Tukey's "D" value§		5			8			n.s.			†	
Male												
Lordville (1965)	116	78	0.9	7	122	9.1	..	..	..	..	..	..
Millbrook (1967)	58	76	1.3	6	121	3.7	..	..	..	..	..	..
Ripley (1965)	56	91	1.3	9	136	5.4	..	..	..	..	..	..
Seneca Army Depot (1967)	27	92	1.4	31	148	2.1	..	..	..	..	..	..
Tukey's "D" value§		6			..			..			..	

* Where no data are given, sample was too small.
§ Values represent weight difference that was significant in each case ($P = 0.05$); n.s. = not significant.
† Analysis of variance showed F to be significant.

TABLE 3. CORRELATIONS AND REGRESSION EQUATIONS BETWEEN DRESSED WEIGHT (IN POUNDS) AND OTHER PHYSICAL INDICES FOR DEER TAKEN DURING POST-SEASON HUNTS

Locality	Female				Male			
	Number	r	Regression equation	$s_{y.x}$	Number	r	Regression equation	$s_{y.x}$
Whole weight (pounds)								
Lordville (1965)	335	0.982	$Y = 0.76X + 1$	4.6	..	..	..	..
Millbrook (1967)	236	0.983	$Y = 0.78X$	4.0	..	..	..	..
Ripley (1965)	144	0.987	$Y = 0.78X + 1$	3.4	..	..	..	..
Seneca Army Depot (1967)	71	0.970	$Y = 0.77X + 1$	4.4	80	0.994	$Y = 0.77X + 2$	3.4
Hind foot length (centimeters)								
Lordville (1965)	226	0.793	$Y = 0.09X + 37$	1.5	..	..	..	..
Lordville (1966)	241	0.827	$Y = 0.10X + 36$	1.4	..	..	..	..
Millbrook (1967)	159	0.851	$Y = 0.10X + 37$	1.4	..	..	..	..
Ripley (1965)	56	0.820	$Y = 0.07X + 39$	1.1	..	..	..	..
Seneca Army Depot (1965)	73	0.723	$Y = 0.07X + 38$	1.4	56	0.823	$Y = 0.08X + 37$	1.6
Seneca Army Depot (1967)	71	0.854	$Y = 0.09X + 37$	1.0	80	0.909	$Y = 0.08X + 38$	1.2
Girth (millimeters)								
Millbrook (1967)	167	0.901	$Y = 4.18X + 453$	46.2	..	..	..	..
Seneca Army Depot (1967)	71	0.918	$Y = 3.24X + 515$	25.8	80	0.930	$Y = 2.87X + 542$	34.9

Kidney weight (grams)

Lordville (1965)	252	0.784	$Y = 0.99X + 24$	19.2	..	..	..	..	..	..
Lordville (1966)	123	0.785	$Y = 0.97X + 18$	17.0	..	..	..	..	..	..
Millbrook (1967)	146	0.687	$Y = 0.70X + 32$	15.3	..	..	..	..	..	..
Ripley (1965)	144	0.732	$Y = 0.85X + 29$	16.9	..	..	..	..	..	..
Seneca Army Depot (1965)	64	0.623	$Y = 0.56X + 47$	14.3	..	0.799	$Y = 0.96X + 15$			20.8
Seneca Army Depot (1967)	61	0.667	$Y = 0.73X + 32$	15.1	70	0.754	$Y = 0.87X + 21$			23.9

Kidney fat weight (grams)

Lordville (1965)	252	0.656	$Y = 2.60X - 62$	72.4	..	..	..	..	..	..
Lordville (1966)	123	0.710	$Y = 2.43X - 53$	53.5	..	..	..	..	..	..
Millbrook (1967)	146	0.472	$Y = 1.95X + 3$	74.7	..	..	..	..	..	..
Ripley (1965)	144	0.592	$Y = 1.73X - 49$	49.8	..	..	..	..	..	..
Seneca Army Depot (1965)	64	0.598	$Y = 2.66X - 63$	72.3	56	0.012	..	..	..	..
Seneca Army Depot (1967)	61	0.582	$Y = 4.95X - 186$	129.3	70	0.048	..	..	..	..

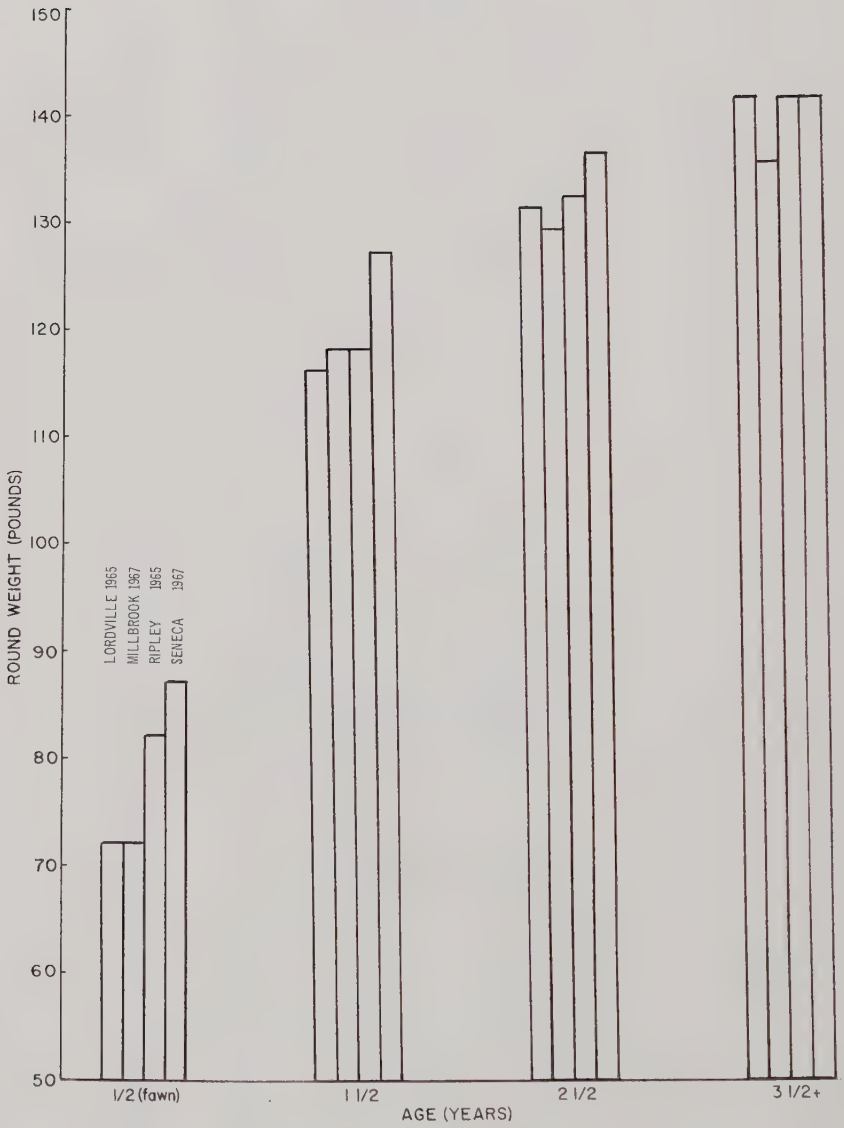

Figure 5. Mean round weight for female deer of different age groups. (Sequence of bars as labeled for fawns is the same for all groups)

2½-year-old females, although weights were lowest at Millbrook and highest at the Seneca Army Depot. For 3½-year-old and older females, deer from Millbrook were significantly lighter than deer from the other areas. Data for 1½-year-old males are included in Table 2, but the sample size was too small for statistical analysis. Nonetheless, males

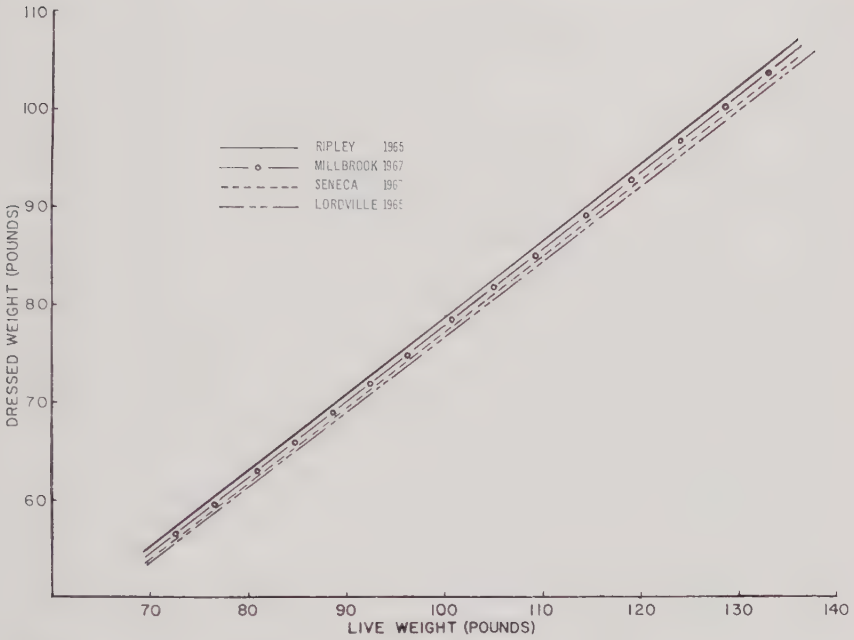

Figure 6. Regression of dressed weight on live weight for female deer.

from both the Seneca Army Depot and Ripley appeared to be heavier than those from Millbrook and Lordville.

For females, the correlation between live weight and dressed weight was highly significant with values of "*r*" ranging from 0.970 to 0.987 (Table 3). Regression of dressed weight on round weight is shown in Figure 6, and the regression equations are similar for all four areas. From these equations, it is apparent that there was a constant relationship between round and dressed weight, regardless of range condition, among these four deer herds, and the regression equation ($\hat{Y} = 0.77X + 1$) should be applicable to all female deer from these areas at least.

For males, only the hunt at the Seneca Army Depot in 1967 produced a sample of both round and dressed weights for all age groups. The correlation was 0.994 ($P < 0.01$), and the regression equation ($\hat{Y} = 0.77X + 2$) was similar to that for females.

Hind Foot Length

Mean hind foot length (Table 4) did not rank the herds in the same order as did weight. For female fawns, hind foot length was lowest at Lordville and highest at Ripley with the Seneca Army Depot and Millbrook intermediate. Male fawns were ranked in the same order, except that at Lordville the mean length was 1 centimeter longer in

TABLE 4. COMPARISON OF MEAN HIND FOOT LENGTH (IN CENTIMETERS) FOR DEER OF DIFFERENT AGES TAKEN DURING POST-SEASON HUNTS*

Locality	Fawn			1½ years			2½ years			3½+ years		
	Number	Mean length	Standard error	Number	Mean length	Standard error	Number	Mean length	Standard error	Number	Mean length	Standard error
Female												
Lordville (1965)	49	41	0.2	39	45	0.3	39	46	0.1	102	46	0.3
Lordville (1966)	51	41	0.2	40	45	0.3	9	45	0.2	61	46	0.5
Millbrook (1967)	42	42	0.3	43	47	0.2	33	47	0.2	45	47	0.2
Ripley (1965)	16	43	0.2	8	46	0.4	11	47	0.3	20	47	0.4
Seneca Army Depot (1965)	24	42	0.2	23	46	0.3	10	45	0.4	15	45	0.3
Seneca Army Depot (1967)	21	42	0.2	23	45	0.3	16	46	0.3	13	46	0.3
Tukey's "D" value§		1			1			2			1	
Male												
Lordville (1965)	86	42	0.2	..	..	..	..	..	..	..	..	..
Lordville (1966)	71	43	0.2	7	47	0.4	..	..	..	..	..	..
Millbrook (1967)	38	43	0.3	6	48	0.8	..	..	..	..	..	..
Ripley (1965)	20	44	0.8	..	..	..	..	..	..	..	..	..
Seneca Army Depot (1965)	20	43	0.3	24	48	0.4	13	48	0.4	6	49	0.4
Seneca Army Depot (1967)	30	43	0.2	32	49	0.3	10	50	0.3	13	49	0.3
Tukey's "D" value§		1			..			..			..	

* Where no data are given, sample was too small.
§ Values represent length difference that was significant in each case ($P = 0.05$).

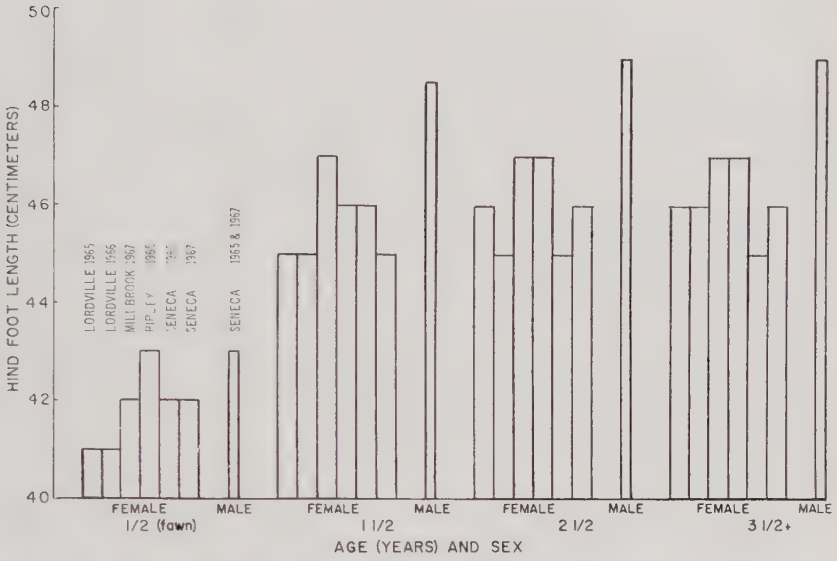

Figure 7. Mean hind foot length for male and female deer of different age groups. (Sequence of bars as labeled for fawns is the same for all groups)

1966 than in 1965. For females 3½ years old or older, the ranking was different (Figure 7). Mean length was lowest at the Seneca Army Depot in 1965 and greatest at Ripley and Millbrook, with the Seneca Army Depot in 1967 and Lordville intermediate. Tukey's "D" value indicates that a difference between means of 1 centimeter was significant (2 centimeters at 2½ years). However, it is questionable whether hind foot length can be measured within an accuracy of 1 centimeter. Error of measurement, plus small sample size, may account for some of the differences between the areas and for some irregularities within areas. For example, at the Seneca Army Depot in 1965, hind foot length increased from 42 centimeters for fawns to 46 centimeters for yearlings and then decreased to 45 centimeters for all older deer. It is doubtful that this was the true relationship in the population, as range conditions and deer numbers remained fairly constant at the Depot from about 1962 to 1967.

Although hind foot length was highly correlated with dressed weight ($P < 0.01$), the regression equations were dissimilar between areas (Table 3). The prediction of hind foot length for deer of equal weights from each of the areas produced estimates which varied by as much as 1 centimeter, and the standard error of estimate was 1 centimeter or larger for all areas. Therefore, the relationship between dressed weight and hind foot length cannot be considered constant enough to use hind foot length as an index of physical condition or range condition.

GIRTH

Girth was recorded only at Millbrook and at the Seneca Army Depot in 1967 (Table 5). Differences in mean girth between the two areas were significant ($P = 0.01$) for both male and female fawns, those from the Depot having the greatest girth. Means for yearling females were similar but were not compared statistically because the variance of girth measurements from Millbrook was too great. Differences in girth were not significant for females 2½ years old and older. Girth was significantly correlated with dressed weight, but the slope of the relationship was different for the two areas with Millbrook having the steeper slope (Table 3). Also, by 2½ years, females at Millbrook had a larger girth than those from the Seneca Army Depot although not significantly so. The standard error of estimate was extremely large, a disadvantage for predicting dressed weight from girth measurements.

EYE LENS WEIGHT

Eye lenses were collected only in 1965, and all findings were reported by Friend and Severinghaus (1967). There were no significant differences in mean lens weight between Ripley and the Seneca Army Depot, so weights from these two areas were combined for comparison with those from Lordville. Mean lens weights from Ripley and the Seneca Army Depot were significantly heavier than those from Lordville for 1½- and 4½-year old females ($P = 0.05$) and for male and female fawns and 2½- and 3½-year-old females.

KIDNEY WEIGHT

There was a significant correlation between kidney weight and dressed weight, and growth curves were similar at ages from fawn to 2½ years. However, for older deer, the curves were markedly different because the kidneys continue to grow while dressed weight does not (Figure 8). The data for both years at the Seneca Army Depot and Lordville were combined because there were no significant differences between years for either of these areas.

Significant differences were few, but it appears that, for all ages, female deer from Millbrook had smaller kidneys than deer from any of the other areas. Fawns from Lordville had smaller kidneys than those from the Seneca Army Depot and Ripley. On these three areas, the relationship changed and kidney weights were approximately equal at an age between ½ year and 1½ years, while for older females kidneys from Lordville in 1965 were significantly heavier than those from the Seneca Army Depot in 1965. With these inconsistencies, kidney weight does not seem to provide a satisfactory base for computing kidney fat indices for different age and sex groups.

These inconsistencies in kidney weights are reflected in different

TABLE 5. COMPARISON OF MEAN GIRTH (IN MILLIMETERS) FOR DEER OF DIFFERENT AGES TAKEN DURING POST-SEASON HUNTS*

Locality	Fawn			1½ years			2½ years			3½+ years		
	Number	Mean girth	Standard error	Number	Mean girth	Standard error	Number	Mean girth	Standard error	Number	Mean girth	Standard error
Female												
Millbrook (1967)	42	702	6.2	45	835	20.4	33	873	6.7	47	887	6.1
Seneca Army Depot (1967)	20	732	7.0	23	841	7.2	16	858	9.0	12	872	6.2
t-value	2.95**			§			1.30 n.s.			1.19 n.s.		
Male												
Millbrook (1967)	40	714	6.5	6	857	17.3	..	..	..	..	..	..
Seneca Army Depot (1967)	27	742	7.6	31	881	6.7	10	958	11.8	11	951	18.3
t-value	2.80**			..			..			..		

* Where no data are given, sample was too small.
§ Means could not be compared because variance was heterogeneous.
** Significant at $P = 0.01$.

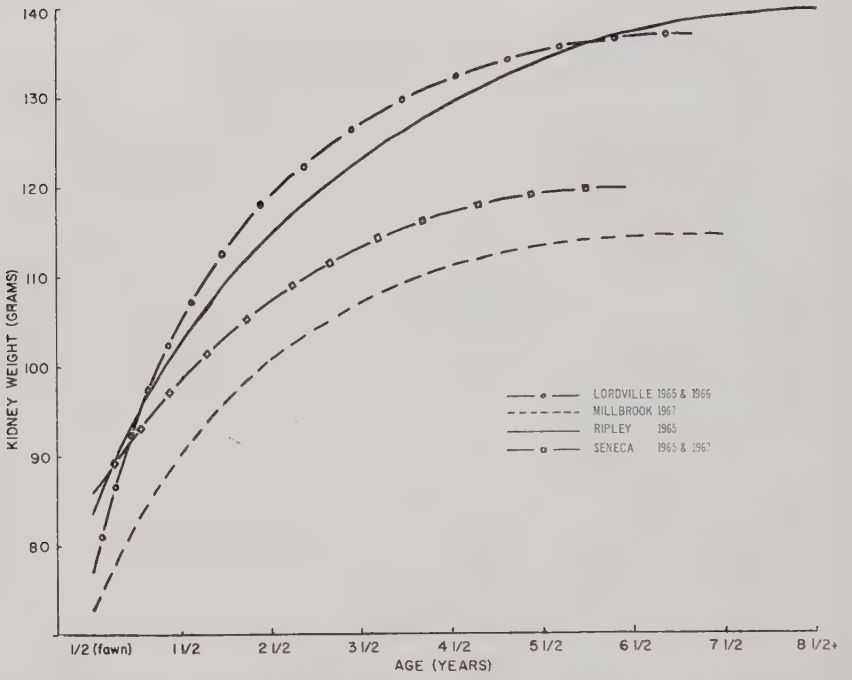

Figure 8. Mean kidney weight (both kidneys combined) for female deer of different age groups.

relationships between dressed weight and kidney weight for the different areas (Figure 9). The slope of the regression varied from 0.56 at the Seneca Army Depot in 1965 to 0.99 at Lordville in 1965 (Table 3). Not only was there a difference in the dressed weight-kidney weight relationship between good and poor range areas, but there was a difference between the two hunts at the Seneca Army Depot where range conditions and deer populations remained fairly constant. Also, the regression equations for males differed from those for females for both hunts at the Seneca Army Depot.

KIDNEY FAT WEIGHT

In mean kidney fat weight, there was an unexpected change in the relative positions of the deer herds (Figure 10). Kidney fat weights were highest at the Seneca Army Depot and lowest at Ripley, with Lordville and Millbrook intermediate (Table 6). The differences between means were not tested for significance because variances for all age and sex groups were heterogeneous ($P = 0.01$) by Bartlett's test for homogeneity of variance. The outstanding digressions were the extremely high weights at the Seneca Army Depot in 1967 and the extremely low weights at Ripley. For females, there was a significant

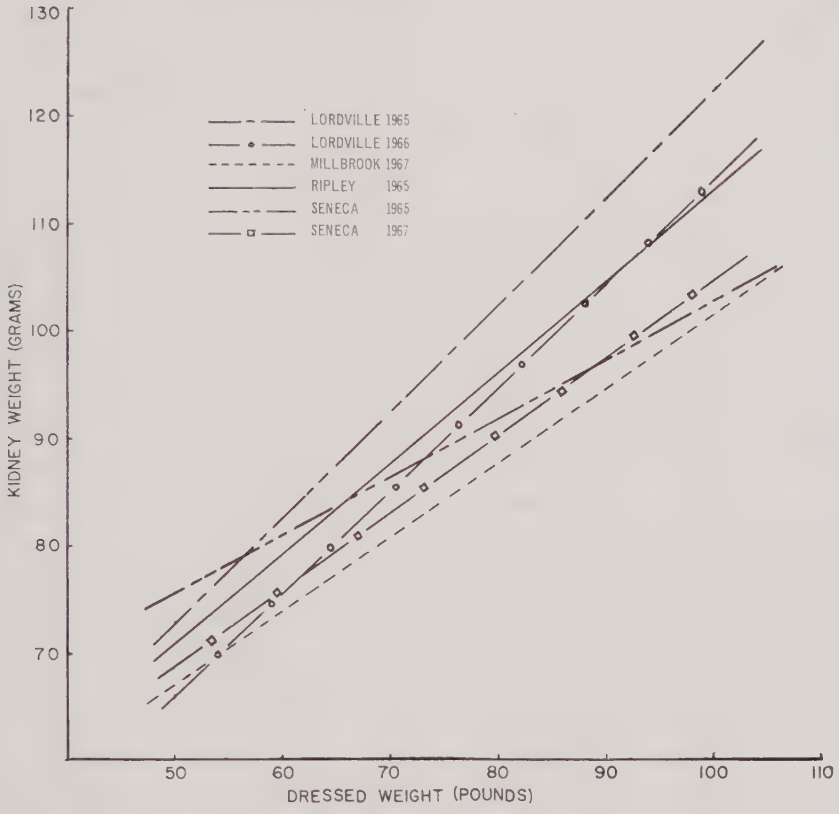

Figure 9. Regression of kidney weight on dressed weight for female deer.

correlation between dressed weight and kidney fat weight (Table 3). There was a fairly consistent pattern of decreasing kidney fat weight in animals 3½ years old and older (Figure 10). There was no consistent relationship between dressed weight and kidney fat weight of the six hunts, although regression equations were similar for Lordville in 1965 and 1966 and the Seneca Army Depot in 1965 (Figure 11).

For males from the Seneca Army Depot, the correlation between dressed weight and kidney fat weight was not significant for either 1965 or 1967 (Table 3).

KIDNEY FAT INDICES

Despite the differences in kidney weights and kidney fat weights between areas and between sex and age groups, mean kidney fat indices were calculated by dividing mean kidney fat weight by mean kidney weight (Table 7). Kidney fat indices ranked the herds essentially the same as did kidney fat weights. The Seneca Army Depot in 1967 had the highest indices, Millbrook and the Seneca Army Depot in 1965

TABLE 6. COMPARISON OF KIDNEY WEIGHT AND KIDNEY FAT WEIGHT (IN GRAMS) FOR DEER OF DIFFERENT AGES TAKEN DURING POST-SEASON HUNTS*

Sex and locality	Fawn			1½ years			2½ years			3½+ years		
	Number	Mean weight	Standard error	Number	Mean weight	Standard error	Number	Mean weight	Standard error	Number	Mean weight	Standard error
Kidney weight												
Female (both kidneys)												
Lordville (1965)	76	79	1.5	36	103	2.9	37	125	3.9	106	132	2.4
Lordville (1966)	40	74	2.1	32	96	2.6	10	112	3.4	50	129	2.6
Millbrook (1967)	34	73	2.0	41	92	2.4	32	101	3.0	42	113	3.0
Ripley (1965)	36	83	2.1	30	104	3.0	24	118	3.8	54	127	2.8
Seneca Army Depot (1965)	22	85	3.5	19	99	2.2	10	102	4.7	15	114	4.9
Seneca Army Depot (1967)	21	83	2.9	19	97	2.5	14	118	5.8	9	112	5.7
Tukey's "D" value§		10			12			20			18	
Male (both kidneys)												
Lordville (1965)	97	81	1.6	7	122	14.7	..	..	..	..	..	..
Lordville (1966)	52	85	1.8	6	98	8.5	..	..	..	..	..	..
Millbrook (1967)	36	75	2.7	6	107	3.8	..	..	..	..	..	..
Ripley (1965)	42	86	2.2	7	127	6.9	..	..	..	..	..	..
Seneca Army Depot (1965)	19	86	4.1	19	117	4.4	12	147	7.2	6	170	7.8
Seneca Army Depot (1967)	28	87	2.1	26	114	3.8	9	139	6.9	11	171	12.4
Tukey's "D" value§		10			..			..			..	

			Kidney fat weight									
Female (both kidneys)												
Lordville (1965)	76	73	4.3	36	215	12.5	37	207	14.7	106	204	8.6
Lordville (1966)	40	81	5.2	32	176	12.9	10	188	22.0	50	196	8.8
Millbrook (1967)	34	116	11.4	41	202	13.0	32	207	14.8	42	179	11.9
Ripley (1965)	36	56	5.7	30	105	8.7	24	149	11.6	54	138	7.9
Seneca Army Depot (1965)	22	117	14.0	19	219	22.3	10	197	26.0	15	197	21.6
Seneca Army Depot (1967)	21	164	14.2	19	294	30.8	14	377	52.0	9	317	60.9
Male (both kidneys)												
Lordville (1965)	97	61	3.9	7	77	18.6	..	..	..	..	..	..
Lordville (1966)	52	73	5.5	6	85	11.8	..	..	..	..	..	..
Millbrook (1967)	36	71	7.0	6	120	29.6	..	..	..	..	..	..
Ripley (1965)	42	57	4.8	7	62	13.1	..	..	..	..	..	..
Seneca Army Depot (1965)	19	120	14.6	19	101	12.0	12	113	20.0	6	90	13.1
Seneca Army Depot (1967)	28	152	16.2	26	155	14.3	9	145	14.2	11	99	12.8

* Where no data are given, sample was too small.
§ Values represent weight difference that was significant in each case ($P = 0.05$).

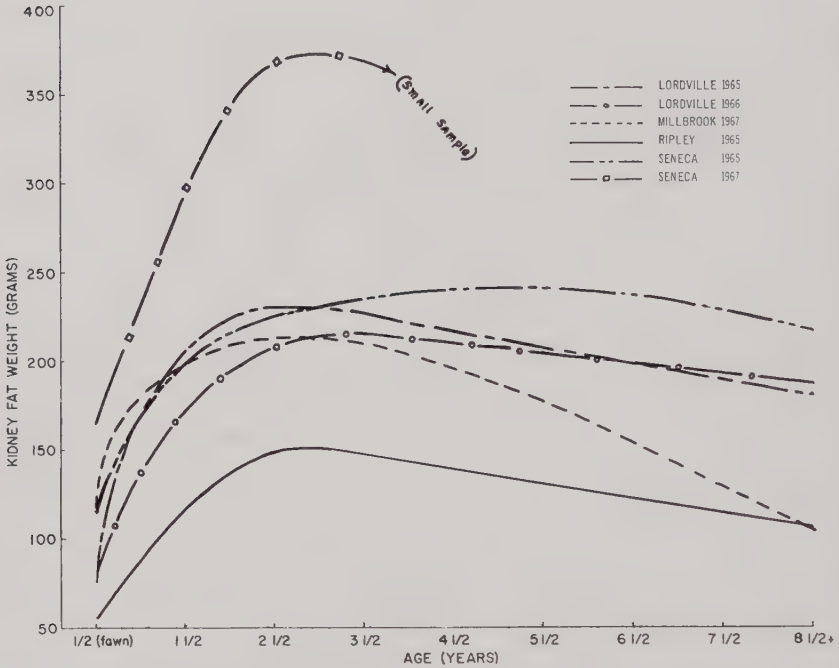

Figure 10. Mean kidney fat weight (both kidneys combined) for female deer of different age groups.

TABLE 7. MEAN KIDNEY FAT INDICES FOR DEER OF DIFFERENT AGES TAKEN DURING POST-SEASON HUNTS*

Locality	Fawn		1½ years		2½ years		3½ years	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Female								
Lordville (1965)	92	2–250	208	41–378	166	49–340	154	36–373
Lordville (1966)	110	32–209	184	76–324	168	96–299	152	37–287
Millbrook (1967)	159	23–432	220	57–391	205	99–512	158	39–380
Ripley (1965)	67	0–210	100	0–200	126	52–250	108	36–244
Seneca Army Depot (1965)	138	56–323	222	122–476	193	48 300	173	95–250
Seneca Army Depot (1967)	198	26–335	303	132–761	320	133–639	283	25–546
Male								
Lordville (1965)	75	13–251	63	26–160	..	..	..	..
Lordville (1966)	86	9–207	87	38–148	..	..	..	..
Millbrook (1967)	95	15–280	112	8–206	..	..	..	..
Ripley (1965)	66	14–247	49	10– 77	..	..	..	..
Seneca Army Depot (1965)	140	69–256	86	30–192	77	21–218	53	39– 66
Seneca Army Depot (1967)	175	51–423	136	50–237	104	47–158	58	37–113

* Where no data are given, sample was too small.

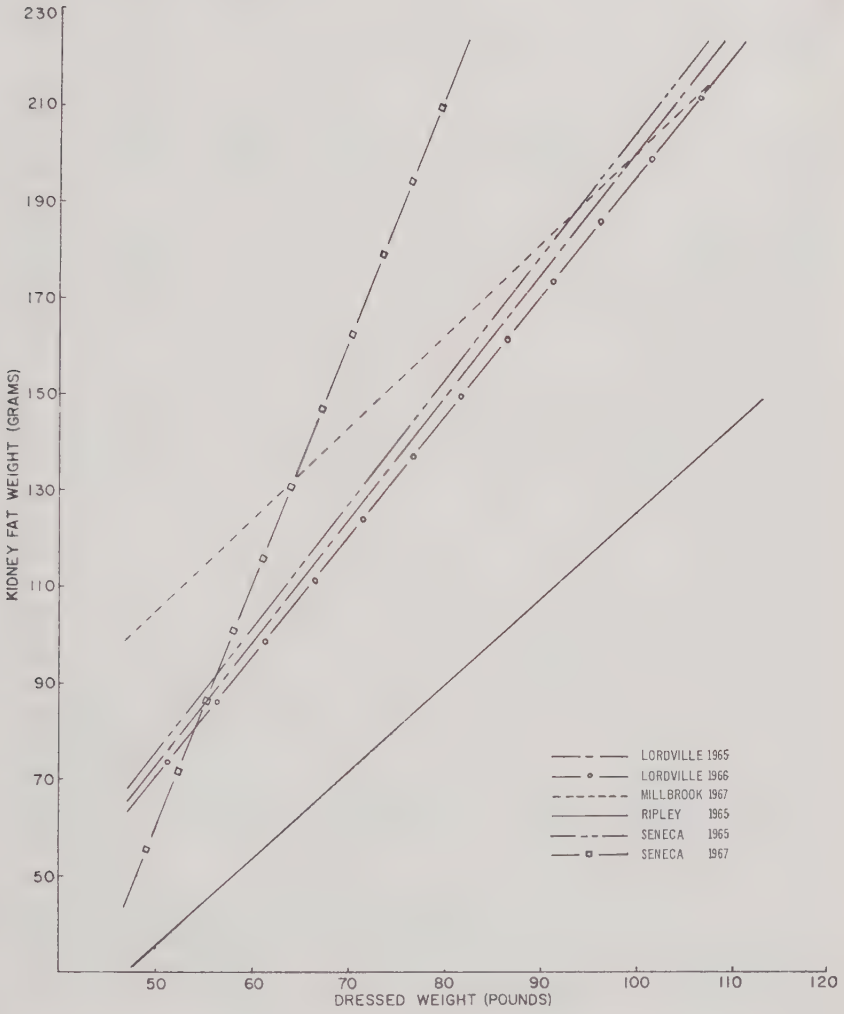

Figure 11. Regression of kidney fat weight on dressed weight for female deer.

the second highest, Lordville third and Ripley lowest. The effect on the kidney fat index of differing regression equations for kidney weight and kidney weight in the different areas can be seen by comparing females of equal dressed weight (Table 8). For females with a dressed weight of 100 pounds, the range in predicted kidney weights was 21 grams and in predicted kidney fat, 185 grams. The Seneca Army Depot in 1965 and Lordville in 1965 had similar regression equations for kidney fat weight (Figure 11) but vastly different equations for kidney weight (Figure 9), and a difference of only 5 grams in kidney fat weight

TABLE 8. PREDICTED PHYSICAL INDICES FOR FEMALE DEER OF EQUAL DRESSED WEIGHT

Locality	Dressed weight (pounds)	Hind foot length (centimeters)	Girth (millimeters)	Kidney weight (grams)	Kidney fat weight (grams)	Kidney fat index (per cent)
Lordville (1965)	100	46	..	123	198	161
Lordville (1966)	100	46	..	115	190	165
Millbrook (1967)	100	47	871	102	198	194
Ripley (1965)	100	46	..	114	124	109
Seneca Army Depot (1965)	100	45	..	103	203	197
Seneca Army Depot (1967)	100	46	839	105	309	294

(Table 8) and 20 grams in kidney weight produced a 36 per cent difference in kidney fat indices.

ANTLER SIZE

Because deer at Lordville, Ripley and Millbrook were subjected to hunting during the regular gunning season, there were relatively few adult males available during the January post-season hunts, and most of those taken had already shed their antlers. An unusual situation prevailed at the Seneca Army Depot where, for some undetermined reason, the bucks retained their antlers through January in both 1965 and 1967. Therefore, antler data collected from yearling males at the Seneca Army Depot were compared with antler data collected from yearling males during the gunning season on the other three areas (Table 9). Data from the Town of Hancock in Delaware County were considered representative of the Lordville area; from the Town of Washington in Dutchess County, of the Millbrook area; and from several towns in northwestern Chautauqua County, of the Ripley area.

Data for both points and beams ranked the yearling males in the same order as dressed weights ranked the yearling females, with Lordville low, Millbrook and Ripley intermediate, and the Seneca Army Depot highest. Differences between beam diameters were not tested for significance because variances were heterogeneous, and differences between mean number of points were not tested because the data were not normally distributed.

Small sample sizes account for some of the heterogeneity in variance, but also, in poor range areas, the distribution of both beam size and points was not normal but skewed to the right. An extreme example was the distribution of points at Lordville in 1966 when 60 per cent of the males had only two points, but the distribution ran to eight points.

TABLE 9. COMPARISON OF MEAN ANTLER SIZE FOR YEARLING MALE DEER*

Locality	Beam			Points		
	Number	Mean diameter§	Standard error	Number	Mean	Standard error
Lordville (1965)	59	16	0.4	59	3	0.1
Lordville (1966)	103	16	0.3	103	3	0.1
Millbrook (1967)	19	20	0.8	19	4	0.3
Ripley (1965)	15	19	0.4	16	5	0.4
Seneca Army Depot (1965)	19	19	0.4	19	6	0.4
Seneca Army Depot (1967)	32	22	0.5	32	6	0.2

* Antler data were collected at Seneca Army Depot during post-season hunts. For the other areas, antler data from the previous big game season were tallied from towns representative of the post-season area.
§ In millimeters.

For 48 adult males which retained their antlers at the Seneca Army Depot in 1967, there were highly significant correlations between round weight and antler beam diameter ($r = 0.760$) and round weight and number of points ($r = 0.594$). The relationship could not be tested for the other three areas because weight data were not available in conjunction with the antler data.

REPRODUCTIVE RATES

A chi-square analysis of the reproductive rates indicated that the data in Table 10 may be divided into two distinct groups. The two

TABLE 10. COMPARISON OF REPRODUCTIVE RATES OF FEMALE DEER OF DIFFERENT AGES TAKEN DURING POST-SEASON HUNTS*

Locality	Fawn		1½ years		2½ years		3½+ years	
	Number	Mean	Number	Mean	Number	Mean	Number	Mean
Lordville (1965)	70	0.06	49	1.17	48	1.77	128	1.77
Lordville (1966)	45	0.09	42	1.38	12	1.83	68	1.76
Millbrook (1967)	58	0.03	67	1.54	42	1.76	57	1.98
Ripley (1965)	45	0.40	36	1.78	34	2.00	66	2.06
Seneca Army Depot (1965)	23	0.48	24	1.83	10	1.90	16	1.81
Seneca Army Depot (1967)	22	0.41	23	1.78	16	1.94	13	1.92

* Pregnancy was determined by the presence of embryos.

Lordville populations together with Millbrook constitute one group, and the two Seneca Army Depot populations together with Ripley constitute the second group.

There was virtually no reproduction among fawns at Lordville and Millbrook, compared with fawn reproductive rates of 0.40 at Ripley

TABLE 11. DRESSED WEIGHT (IN POUNDS) OF FEMALE FAWNS IN RELATION TO PREGNANCY

Locality	Pregnant			Non-Pregnant			*t*-value
	Number	Mean weight	Standard error	Number	Mean weight	Standard error	
Ripley (1965) . . .	13	68	1.3	17	59	1.7	3.97**
Seneca Army Depot (1965) .	11	71	1.6	10	61	2.3	3.58**
Seneca Army Depot (1967) .	8	69	1.7	7	65	3.8	1.06

** Significant at the 1 per cent level of confidence.

and 0.41 and 0.48 at the Seneca Army Depot in 1965 and 1967, respectively. These differences were related to the differences in weight between animals from the good and poor range areas. There was a significant difference at Ripley and the Seneca Depot in 1965 between weights of pregnant and non-pregnant fawns (Table 11). At the Seneca Depot in 1967, the corresponding difference was not significant. There seems to be a threshold dressed weight of between 65 and 70 pounds that is related to a female fawn's ability to breed. Since mean dressed weights of fawns from Lordville and Millbrook were well below this threshold (Table 2), virtually no breeding would be expected, and this is what occurred.

DISCUSSION

Standard indices for measuring the physical condition of individual deer are limited. Dressed weight and hind foot length are commonly used for all sex and age groups. Antler size is limited to adult males. The reproductive rate of female deer is practical only in comparing groups of female deer with other groups or with a standard. It is not practical for comparing individuals because even on the best of ranges there are occasional deer that do not become pregnant and on poor range there are occasional individuals that conceive at higher-than-usual rates. Still another index is determination of the percentage of fat present in the bone marrow, usually of the femur bone (Cheatum, 1949). This is an especially valuable tool because it is possible to measure the fat percentage weeks and even months after death of the animal. However, it is limited in scope to animals that have already declined physically to some extent.

In the normal utilization of fat in response to a decline in nutrition, the fat reserves are depleted in the following order (1) subcutaneous fat, (2) fat on the stomach and intestines, (3) fat around the kidneys

and (4) bone marrow fat (Harris, 1945). Further, those bones lying closest to the body proper have their bone marrow depleted sooner than do those of the extremities. Cheatum (1949) suggested that this possibly occurs, and it has since been confirmed by direct observation by project personnel. Thus, the bone marrow fat index is usable only for measuring physical condition after the deer have already declined physically to some extent. A recent study (Ransom, 1965) has shown that there appears to be a rather abrupt decline in bone marrow fat content once the fat present on the kidneys (and presumable other internal organs) reaches a certain level. Ransom plotted the kidney fat index against the percentage of femur fat as the kidney fat index declined from a high of 150 to about 30. As the kidney fat index dropped below this level, however, the femur fat percentage decreased sharply. At these low levels any correlation between the two indices appeared quite irregular.

Ransom's results are obscured somewhat by the fact that he did not distinguish ages of the 34 deer involved. He made no distinctions among age groups because fawns, yearlings and adults showed similar relationships between measurements of the two fat deposits. His sample size was rather small (10 fawns, 4 yearlings and 20 adults) especially since they were collected over a 4-month period. It does seem apparent that distinct age groups should be tested. Metabolic requirements of deer vary with age, season and reproductive activity; also fat levels of fawns rarely are as great as those of older deer. Therefore, it seems likely that utilization of fat resources would differ between various age groups when adequately sampled.

Examination of data presented in Table 3 indicates positive correlations between dressed weight and kidney weight and dressed weight and kidney fat weight for female deer. In every case the slope for kidney fat in relation to dressed weight (Figure 11) is greater than that for kidney weight in relation to dressed weight (Figure 9). This means that, as dressed weight increases, kidney weight increases, but kidney fat increases at a more rapid rate, so, the heavier the deer, the higher the kidney fat index should be. However, the large variance in both kidney weights and kidney fat weights, and the differences in the regressions of these on dressed weight between the four areas, creates a large variance in kidney fat indices. One would expect that within each sex and age group similar kidney fat indices would indicate similar physical condition, but this is not the case. In Table 12, kidney fat indices from selected female fawns approximate 100 per cent, but dressed weights vary from 43 to 71 pounds, and kidney weights vary from 48 to 100 grams. This seems to make the kidney fat ratio technique a questionable one for measuring the relative physical condition of individual deer. A 43-pound fawn is certainly at a disadvantage,

TABLE 12. COMPARISON OF PHYSICAL CONDITION OF FEMALE FAWNS WITH SIMILAR KIDNEY FAT INDICES

Locality	Dressed weight (pounds)	Kidney weight (grams)	Kidney fat weight (grams)	Kidney fat index (per cent)
Lordville (1965)	43	48	50	104
	48	78	71	91
	55	80	76	95
	61	100	98	98
Lordville (1966)	50	60	60	100
Millbrook (1967)	64	53	49	92
Ripley (1965)	64	88	86	98
	71	84	78	93
Seneca Army Depot (1965)	62	68	72	106
Seneca Army Depot (1967)	58	62	58	94

compared with a 71-pound fawn, regardless of equal kidney fat ratios. A similar situation was noted in sheep by Palsson and Verges (1952, Part II). Lambs raised on two nutritional levels were compared at a dressed carcass weight of 30 pounds. There was no significant difference between the groups in kidney fat weight, but a highly significance ($P = 0.01$) in kidney weight, with kidneys from high-level lambs averaging 21 grams heavier than those from low-level lambs. This, in essence, would mean that the poorer specimen would have a higher kidney fat index than would the better ones. They also found that females have significantly more kidney fat than wethers (castrated male sheep) at equal dressed weight.

Project data collected elsewhere, and at different times of the year, also indicate that there are other variables in kidney weight analyses. Briefly, these data suggest that there may be seasonal variations in kidney weight associated with stress or growth.

Further, using kidney fat ratios to measure relative physical condition between deer herds from different areas may also be misleading. As an example, these ratios from Lordville in 1965 were considerably higher than those from Ripley (Tables 6 and 7). All other indices indicated that the deer at Ripley were much better specimens than those at Lordville. One can only surmise that fall range conditions, i.e., heavy mast crops at Lordville and relatively poor mast crops at Ripley accounted for the tremendous difference in kidney fat levels. Also, data for male deer from the Seneca Army Depot (Tables 6 and 7) indicate that the younger deer had higher kidney fat weights and kidney fat indices. This probably was because the older males had just gone through the

breeding season, a period of increased activity and metabolism. Other indices reflect the condition of the previous winter, spring and summer ranges to a large extent. For example, higher reproductive rates for fawns and yearlings indicate that the deer at Ripley have better winter and spring range conditions than do those at Lordville. Better developed antlers on yearling males again indicate better winter range conditions, and probably to some extent better spring and early summer conditions exist on the range at Ripley than on that at Lordville. Winter and early spring conditions also affect dressed weight — the range at Ripley again being better. The deer at Ripley obviously were in better condition than those at Lordville going into the summer. Summer range conditions probably were not dissimilar between the two areas. Thus it seems that kidney fat ratios (and indeed all fat deposits) are quite sensitive to even relatively short-range difference in diet. Further, it must be pointed out that there is some question concerning the reliability of this technique as currently used. Further work is needed to relate total kidney fat weight to some standard and compare these ratios with those derived by the "Riney" technique. There still is the possibility that late-summer range conditions might differ markedly between the two areas, favoring Lordville, but if such a situation does exist it would seem likely that the difference in dressed weights between the two groups would not be so great.

Dressed weights seem to be a reliable indicator of the important differences between deer herds (i.e., in the fawn and yearling age groups) and between individual deer. Thus it does not seem necessary to resort to kidney fat ratios to assess physical condition. Several authors working with sheep have found that, at all stages of growth, a starvation diet produces a striking loss of protein even though fat provides the largest source of energy. Alexander (1962) in starving newborn lambs found that fat and carbohydrate reserves appeared to be exhausted near death, but that protein utilization increased progressively throughout starvation. Clawson and Meyer (1964) starved 5-month-old wethers for 42 days and found that restriction to only 84 per cent of the control feed intake produced a significant difference ($P = 0.05$) in the protein weight of the empty body, but no significant difference in the fat weight of the empty body, compared with that of the controls. They concluded that the caloric content of weight loss was the same, or less, than that of weight gain (i.e., more protein lost than gained). Blaxter (1962) starved adult wethers and found that weight loss in four days of fasting included about 24 per cent protein and 76 per cent fat. Panaretto (1964) found two starvation syndromes in ewes. Ewes with a fat content of 25 per cent body weight showed depletion of both fat and protein reserves until the fat

reserves had been almost completely used. Ewes with a fat content of 40 per cent body weight after a time refused to eat and died in a fat condition. Even animals which have high fat reserves, when abruptly shifted to a protein-deficient diet, will begin catabolizing their own protein as a source of nitrogen. Thus, one must be quite cautious about interpreting animal condition in relation to fat reserves only.

Other physical indices are useful for situations where dressed weight cannot be obtained. Although hind foot length has often been used, its narrow range and lack of a standard measurement technique make other alternatives desirable. Gunn (1964) raised sheep on high, medium and low levels of nutrition during their first winter and then treated them identically throughout their adult lives. Changes in girth were closely related to changes in round weight. He found that body length, pelvis length and pelvis width were most affected, and leg measurements least affected, by nutritional differences. In raising steers on three planes of nutrition for their first winter, Lawrence and Pearce (1964, Part I) found that, in general, girth of the body was affected to a greater extent than height, with length intermediate. When underweight steers were brought up to the weight of the high-plane group, differences in measurements ceased to be significant (Lawrence and Rearce, 1964, Part II). Joubert (1954) also found that, in cattle raised on different nutritional levels, chest width, girth and depth were most affected and leg measurements least affected, with body length intermediate. Leg measurements are affected least because, during periods of undernutrition, the skeleton is affected along the gradient of the maturity of the bones (Palsson and Verges, Part I). Bones of the extremities mature first and are least affected, while bones closer to the trunk would be affected to a greater extent, and trunk bones, which mature last, would be affected most. Thus, girth measurement as an indication of range condition probably is a technique that needs to be investigated further as an alternative index to physical condition when dressed weight cannot be obtained, especially for fawns. However, the relationship between girth and weight should be known for different range conditions.

With the exception of eye lens weight, none of the indices showed significant differences between the herds for females 2½ years old and older. Even if females were undernourished as fawns and yearlings, they eventually reached the same weight and stature as females from good range. Reproductive rates of adult females raised on poor range remained lower, but not significantly so, than those of females raised on good range. This apparently is relative. We have determined reproductive rates for deer from areas where the range was even worse than that at Lordville (central Adirondacks, other areas in the Cat-

skills, Vermont and Antocosti Island in Canada). Reproductive rates for adult females from some of these areas were less than 1.00 embryo per doe.

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GROWTH AND CHEMICAL COMPOSITION OF AQUATIC PLANTS IN TWENTY ARTIFICIAL WILDLIFE MARSHES[1]

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ABSTRACT

Measurements of the standing crop of aquatic plants were made in 20 artificial marshes in the summers of 1968, 1969 and 1970, some 10 years subsequent to construction of the marshes. One sample was taken in June of 1968, and samples were taken in June and August of 1969 and 1970. Botanical separation of the plant material was made on the samples taken in 1969 and 1970. Chemical analyses of the plant tissue were made on the August 1969 sample and on both samples taken in 1970. The dominant plants found in the marshes belonged to the genera *Scirpus* and *Chara*. *Scirpus* dominated the shallow marshes and made up about three-fourths of the total plant material in the 1-foot marshes. *Chara* dominated the deeper marshes and made up nearly two-thirds of the total vegetation in the 3-foot marshes. Above-ground standing crops ranged from about 800 grams per square meter in the shallow marshes down to about 300 grams per square meter in the deepest marshes. The standing crop of the emergent vegetation was three to five times greater that of the submergent vegetation. The submergent vegetation, particularly *Chara,* was characterized by a very high ash content. The calcium content of *Chara* was 20 per cent in contrast to 0.5 per cent for *Scirpus*. For all species the nitrogen content generally ranged between 1 and 2 per cent while the phosphorus content was above 0.1 per cent, and little difference was noted between the submergents and the emergents. *Scirpus* was notable for its low magnesium content, while the potassium content of *Chara* was substantially lower than that of any other species. The manganese and iron content of the submergent species was highly variable but in general was higher than that of the emergent species.

Artificial wildlife marshes have been developed in many areas to enhance the habitat for waterfowl. In most of these marshes, the vegetation has been allowed to invade the flooded areas naturally although in some areas desirable species have been introduced into the marsh by one means or another. As reported earlier (Cook and Powers, 1958), the productivity of these marshes may vary considerably and the vegetation may undergo changes with time.

The purpose of this report is to characterize the vegetation found in 20 one-tenth-acre marshes some 10 years after their establishment. The species found, total above-ground dry matter present and the chemical composition were measured.

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PROCEDURE

The 20 one-tenth-acre impoundments used in this experiment were constructed on a Langford silt loam soil which is acid in the surface horizons although the underlying glacial till is neutral to mildly calcareous. In constructing the dikes around each marsh, the soil material from the marsh basin was excavated down to or into the glacial till material. At values of 7.0 to 7.5, the pH of the marsh bottom soil was, therefore, that of the underlying glacial till rather than the more acid upper horizons of the soil.

The experiment was designed to measure the influence of water depth, soil reaction and organic matter level on the growth of rooted aquatics. Water depths were varied from 1 to 3 feet by ½-foot increments. Additions of organic matter and limestone were made to the marshes so that the experiment consisted of an unreplicated factorial of 5 water depths x 2 soil reactions x 2 organic matter levels for a total of 20 impoundments.

To those marshes which received limestone, 10 tons per acre (1 ton per marsh) were added and mixed with the soil. Organic matter in the form of a productive organic soil was added at the rate of 40 tons per acre (4 tons per marsh) to those marshes receiving additional organic matter. To preclude the lack of nutrients when establishing the vegetation, mineral fertilizer (5-10-5) was added to each marsh before flooding at the rate of 300 pounds per acre (30 pounds per marsh).

Each of eight aquatic species was planted in four randomly distributed 4 x 10-foot subplots within each marsh. The species planted were: *Sparganium americanum, Zizania aquatica, Polygonum amphibium* and *Scirpus acutus* as emergents; *Najas flexilis, Chara* sp, *Potomageton pectinatus* and *Vallisneria americana* as submergents. These species were selected for their potential to provide shelter and food for waterfowl. It was the intent in each of the marshes to maintain each species in the subplot in which it had been planted so that a record of its production could be followed over the course of the experiment. During the growing seasons of 1968, 1969 and 1970, vegetation in each marsh was sampled by placing at random a quadrat (1.0 meter on a side) in each quarter of the marsh and harvesting all above-ground plant material, both submergent and emergent, present within the quadrat. The four samples thus obtained from each marsh were combined, and the dry weight was determined. One sample was taken in June of 1968, while in the two subsequent years samples were obtained in both June and August. In 1969 and 1970, botanical separations of the harvested plant material were made, and the dry weight of each separate was determined.

In 1971, four marshes were drained and the entire standing crop of each marsh was harvested. Two 1-foot-deep marshes and two 3-foot-

deep marshes were used. In one of the 1-foot marshes which consisted entirely of *Scirpus,* roots and rhizomes were harvested from 1-square-meter quadrats to obtain an estimate of the below-ground production of this plant.

Plant samples taken in August of 1969 and June and August of 1970 were analyzed for total nitrogen by the Kjeldahl method. For other elements, plant samples were ashed overnight in quartz crucibles at 500° C. The ash was treated with nitric acid, dried, heated to 400° C, cooled and taken to dryness with hydrochloric acid. The residue was dissolved in 1 normal hydrochloric acid containing 0.5 per cent lanthanum. Phosphorus was determined by the molyb-divanadophosphoric acid method of Kitson and Mellon (1944). Calcium, magnesium, manganese and iron were determined by atomic absorption spectrophotometry using lanthanum to minimize anion interference, while potassium was determined by flame emission spectrophotometry.

RESULTS AND DISCUSSION

The results are presented and discussed separately with respect to the nature of the vegetation in the marshes and its mineral composition.

Plant Growth and Species Distribution

It was the intent when the experiment was begun to maintain the introduced species in each marsh in the subplots in which they had been planted. During the first two years, the invader species were removed from the subplots. It soon became evident, however, that it was impossible to maintain the individual subplots and, therefore, the vegetation was allowed to take its own course over the duration of the experiment. As described in detail by Lathwell et al. (1969), by 1967 the vegetation in the marshes appeared to have stabilized. Vegetation surveys indicated that emergents began to dominate the shallower marshes after 1964. The main emergent was *Scirpus,* with *Typha* coming into some marshes. *Chara* was the dominant submergent. While it dominated the deeper marshes it was found rather widely distributed regardless of depth.

In 1968, 1969 and 1970, therefore, measurements of the standing crop of macrophytes were made. In 1969 and 1970, botanical separations were made of the harvested plant material. Analysis of variance of the standing crop in the marshes was made on the individual harvests. The lime and organic matter additions made when the marshes were constructed had no effect on the standing crop of macrophytes measured. The standing crop found in the marshes was influenced by water depth, and therefore a regression analysis of standing crop on water depth was made.

The standing crops measured in the marshes as a function of water depth are given in Table 1 along with regression estimates and the correlation coefficients obtained. The variation in standing crop from sampling to sampling was likely random since the quadrat was placed in each quarter of the marsh being sampled. No particular reason was apparent for the lower standing crop measured in August of 1970. There was no evidence from visual observations that the marshes had changed at the time the August 1970 samples were taken. As shown by the regression estimates, there was an inverse relationship between water depth and standing crop. The correlation coefficients are reasonably high indicating that production was closely associated with water depth. The relationship was reasonably consistant for the several sampling periods also. Boyd (1968) summarized standing crop data for pure stands of several species of macrophytes and his reported values are generally somewhat higher than the values for the mixed vegetation found in these marshes. It should be noted, however, that several of his values are for the maximum level for several estimates made at different dates. Many of these values were measured in areas where, as noted by Odum (1957) and Penfound (1956), the growing

TABLE 1. STANDING CROP MEASURED IN MARSHES AS A FUNCTION OF WATER DEPTH AND LINEAR REGRESSION ESTIMATES AND CORRELATION COEFFICIENTS (*r*) FOR RELATIONSHIP BETWEEN WATER DEPTH AND STANDING CROP

Item	June 1968	June 1969	August 1969	June 1970	August 1970	Average
			Standing crop (grams per square meter)*			
Water depth (feet)						
1.0	833	749	1,110	871	690	851
1.5	609	559	889	601	544	640
2.0	322	395	471	308	295	358
2.5	299	400	396	233	232	312
3.0	355	361	485	244	208	331
Average	484	493	670	451	394	xxx
			Regression estimates			
Intercept	1,018	871	1,382	1,108	908	xxx
Slope	−261	−187	−349	−324	−255	xxx
			Correlation coefficient			
Crop vs depth	−0.718	−0.582	−0.689	−0.766	−0.784	xxx

* Each value is the average from four marshes.

season is much longer than it is in New York. McNaughton (1966) showed that production of *Typha* varied widely depending on the location sampled with the higher standing crops being measured under the longer growing season. In general, however, the standing crops given in Table 1 are within the range of the values reported by Boyd in his summary of other data recorded in the literature.

Botanical separations of the vegetation in the marshes revealed that many species were present. Of those introduced in 1960, most were still found in a few of the marshes at least. In addition, species other than those introduced were found in many of the marshes. These included *Typha, Elodea* and several of the pondweeds (*Potomageton*). Except for isolated marshes, the bulk of the standing crop, however, was made up of *Scirpus* and *Chara*. The other species, although present, with few exceptions, made up less than 25 per cent of the total standing crop. The chief contributor to the standing crop, except for *Scirpus* and *Chara,* was usually *Typha* or *Vallisneria*. The potomagetons, while present, contributed little to the total standing crop.

The standing crop of *Scirpus* and the percentage it contributed to the total standing crop are given in Table 2. The regression estimates indicate that the contribution of *Scirpus* to both total dry matter and the percentage of the total dry matter decreased with increasing water depth. The correlation coefficients indicate this was a reasonably strong relationship. Since emergent *Scirpus* began to become dominant after 1964, it is possible that it may be continuing to invade the shallower marshes. In the 1-foot-deep marshes, it made up about 75 per cent of the total dry matter found, while in the 1.5-foot-deep marshes it made up only about 55 per cent of the total dry matter. Penfound (1956) observed that most emergent species occur in water less than 1 foot deep. Rickett (1924) in his study of Green Lake, Wisconsin, found that *Scirpus* was present only at water depths of less than 1 meter. Rich et al (1971) reported that *S. acutus* was found in a marl lake only at depths of less than 0.5 meter. The standing crops he measured ranged from 45 to 615 grams per square meter and, on the average, *Scirpus* made up about 25 per cent of the total dry weight for material from water depths of 0 to 1 meter. From visual observation, *Scirpus* seems to be making little, if any, inroad in the deeper marshes, although where it was established it has remained and does contribute to the total dry matter in the marsh. In the shallow marshes, at least, its growth habit is such that it continues to grow outward in a regular manner from the point of initial establishment until it has occupied the entire area. Under these conditions, few other rooted emergents seem able to compete with it and only isolated plants of other species remain. *Chara* has persisted, however, in most of these marshes. Whether it will eventually disappear remains to be determined.

Concerning the distribution of *Chara* in the marshes, it is evident from the data in Table 3 that the standing crop was not related to water depth. While there was substantial variation from marsh to marsh, the average standing crop was similar regardless of water depth. In relation to the total production of aquatic plants, there was a tendency for the percentage of *Chara* to increase as the water depth increased. This relationship occurred not as a result of increased growth of *Chara* at the deeper depths but as a result of reduced growth of other species. The correlation coefficients indicate this relationship to be reasonably strong. Thus, the growth of *Chara* evidently is rather insensitive to water depth while other species in these marshes are less tolerant of the deeper water.

Forsberg (1960) reported standing crops of *Chara* of over 1,100 grams per square meter, while Rickett (1924) reported 35 to 130 grams per square meter for Green Lake in Wisconsin. In their studies of Michigan ponds, Knight et al. (1962) reported standing crops of from 120 to 490 grams per square meter with *Chara* being the most important contributor. Thus, our values were somewhat higher than the lowest values and substantially lower than the highest values reported.

Most of the evidence indicates that *Chara* is found in waters less than 3 meters deep. In Green Lake, Rickett (1924) found relatively more *Chara* at depths greater than 1 meter, where it made up 58 per cent of the dry weight at 1 to 3 meters and 44 per cent of the dry weight at from 3 to 8 meters. He noted, however, that at depths of from 0 to 1 meter *Chara* made up 35 per cent of the dry weight recorded, although at 0 to 1 meter the dry weight averaged 67 grams per square meter compared with 220 at from 1 to 3 meters and 177 at from 3 to 8 meters. Forsberg (1960) found *Chara* confined to waters less than 3 meters in depth. Rich et al. (1971) found *Chara* to depths of 5 meters although it was generally found between 0 and 2 meters.

The standing crop from a 1-foot-deep marsh consisting of only *Scirpus* and harvested August 20, 1971 is given in Table 4. Since the entire marsh was harvested, the figures give a reliable estimate of the total material in the marsh. This total was quite large, and the contribution each year was substantial since the remains from the previous year's growth and the growth for the current year were very close to the same quantity. Apparently the old plant material breaks down rather slowly since the previous year's growth remained in such a large quantity. The figures for the current-year standing crop for 1971 are quite similar to the values given in Table 2 so that the latter are likely reasonable estimates of the current-year standing crop. Most striking, however, is the dry weight of the roots and/or rhizomes which constituted about three-quarters of the total dry weight of the plant. Bray et al. (1959)

TABLE 2. STANDING CROP OF *Scirpus* AND ITS PERCENTAGE OF TOTAL STANDING CROP AS A FUNCTION OF WATER DEPTH AND LINEAR REGRESSION ESTIMATES AND CORRELATION COEFFICIENTS FOR RELATIONSHIP BETWEEN WATER DEPTH AND STANDING CROP

Item	June 1969		August 1969		June 1970		August 1970		Average	
	Yield	Percentage of total	Yield	Percentage of total	Yield	Percentage of total	Yield	Percentage of total	Yield	Percentage of total
	Standing crop or yield (grams per square meter) and percentage of total*									
Water depth (feet)										
1.0	509	68	866	78	671	77	538	78	646	73
1.5	307	55	498	56	349	58	299	55	363	56
2.0	209	42	151	32	108	35	139	47	152	39
2.5	152	38	87	22	89	38	86	37	104	34
3.0	58	16	78	16	20	8	56	27	53	17
Average	247	xx	336	xx	247	xx	224	xx	xxx	xx
	Regression estimates									
Yield										
Intercept	732		1,213		942		717		xxx	
Slope	−224		−412		−334		−232		xxx	
Percentage of total										
Intercept	92		104		107		96		xxx	
Slope	−24		−32		−31		−24		xxx	
	Correlation coefficient									
Yield vs depth	−0.551		−0.711		−0.742		−0.660		xxx	
Percentage of total vs depth	−0.504		−0.685		−0.707		−0.492		xxx	

* Each value is the average from four marshes.

TABLE 3. STANDING CROP OF *Chara* AND ITS PERCENTAGE OF TOTAL STANDING CROP AS A FUNCTION OF WATER DEPTH AND LINEAR REGRESSION ESTIMATES AND CORRELATION COEFFICIENTS FOR RELATIONSHIP BETWEEN WATER DEPTH AND STANDING CROP

Item	June 1969		August 1969		June 1970		August 1970		Average	
	Yield	Percentage of total	Yield	Percentage of total	Yield	Percentage of total	Yield	Percentage of total	Yield	Percentage of total
Standing crop or yield (grams per square meter) and percentage of total*										
Water depth (feet)										
1.0	180	24	144	13	192	22	90	13	152	18
1.5	218	39	258	29	174	29	44	8	174	26
2.0	209	53	193	41	176	57	109	37	172	47
2.5	204	51	174	44	107	46	121	52	199	48
3.0	256	71	267	55	198	81	98	47	205	64
Average	213	xx	207	xx	169	xx	92	xx	xxx	xx
Regression estimates										
Yield										
Intercept	88		68		115		59		xxx	
Slope	49		59		18		8		xxx	
Percentage of total										
Intercept	5		−4		−12		−13		xxx	
Slope	21		20		29		22		xxx	
Correlation coefficient										
Yield vs depth	0.330		0.391		0.123		0.073		xxx	
Percentage of total vs depth	0.501		0.572		0.655		0.527		xxx	

* Each value is the average from four marshes.

showed that the underground portions of *Typha* are about double the above-ground portions. They reported measurements of from 2,600 to 2,900 grams per square meter for underground organs. McNaughton (1966) also reported that some two-thirds of the total dry weight of *Typha* consisted of the underground portions of the plants for which he gave values of from 900 to 2,600 grams per square meter. Both *Typha* and *Scirpus,* therefore, fix large quantities of organic matter in underground storage organs.

An estimate of net production rates of *Scirpus* can be made from the data in Table 4. Since growth begins about May 1 in this area, about 100 days transpired from the beginning of growth to the time of

TABLE 4. STANDING CROP OF *Scirpus*, MEASURED IN A MARSH WITH A WATER DEPTH OF 1 FOOT, HARVESTED AUGUST 20, 1971

Crop	Dry weight (grams per square meter)	Ash (per cent)
Current year	786	3
Previous year	702	5
Roots	2,664	39

harvest in August. Thus, net productivity was about 7.9 grams per square meter per day in this season. Reported values of primary productivity, in terms of grams per square meter per day, vary from about 1.0 (Edwards and Owens, 1960) to 9 (Owens and Edwards, 1962). Odum (1957) reported values much higher than these, but his values represent gross productivity and apparently do not take into account respiration, while the other reported values represent net productivity.

Penfound (1956) reported some extremely high values of net productivity (50 grams per square meter per day) for *Typha* over short growing periods. It is likely that values of the same order would be found for *Scirpus* since its growth habit is similar to that of *Typha*. The very high values of net productivity may well be accounted for by the fact that both the products of photosynthesis and the root reserves are being utilized during the grand period of growth of the above-ground portion of the plant. Once the major portion of the above-ground growth is made, the products of photosynthesis are then used to replenish the root reserves used previously in growth. On theoretical grounds (de Wit, 1965), it is unlikely that rates of photosynthesis could be sufficiently great to provide for dry weight accumulation rates of 50 grams per square meter per day. Therefore, the stored root reserves of plants such as *Typha* and *Scirpus* must be utilized

during the periods of most rapid growth. The rate of replenishment of storage products in roots is not known, but our values for net productivity seem reasonable for plants such as these.

The evidence from these marshes indicates that the standing crop produced by emergents was several times greater than that from submerged species. In the marshes drained and sampled in 1971, the one with only submerged species had a standing crop of about 180 grams per square meter while those in which emergent species were dominant had standing crops ranging from about 530 to 780 grams per square meter. The samples taken in 1969 and 1970 provided essentially the same results. Thus, it seems fair to conclude that the net productivity of the emergent species as estimated from standing crop measurements was substantially greater than that of the submergent species in these marshes. Forsburg (1960) concluded also that submergent species have very low production rates compared with many terrestrial plants. In accordance with Westlake (1963), it may be concluded that our values of net productivity and measured standing crop were within the range of accepted values and that net productivity of submerged vegetation is not likely to approach that of emergent or strictly terrestrial vegetation. Furthermore, from our estimates and those reported by Westlake (1963) some recorded values for net productivity of emergent aquatic communities appear to be unrealistically high.

MINERAL COMPOSITION

The ash and macronutrient contents of the plant samples taken in August 1969 and in June and August of 1970 are given in Tables 5, 6 and 7. Where more than one sample was harvested, the results of the analyses are given as the mean and the standard deviation about that mean. There were variable numbers of species since the samples from each marsh were taken separately and each species was not necessarily found in every marsh.

ASH There was a wide variation in the ash content of the various plants found in the marshes. Most notable were the values for *Chara* and for *Typha* and *Scirpus*. The extremely high values for *Chara* are typical for this species; reported values range from 30 per cent (Gortner, 1934) to 81 per cent (Boyd and Lawrence, 1966) and include 41 per cent (Schuette and Alder, 1929), 58 per cent (Forsberg, 1960) and 43 per cent (Boyd and Lawrence, 1966). Boyd and Lawrence (1966) reported that the ash content of *Chara* increases as the alkalinity of the water increases. The ash values of from 66 to 69 per cent found in our studies are high compared with most values reported, and the alkalinity of the water was quite high (Lathwell et al., 1969).

The ash content of the emergents *Typha* and *Scirpus* was low and quite consistent among the three sampling times. The values of 5 to 8

TABLE 5. ASH AND MACRONUTRIENT CONTENT OF SEVERAL AQUATIC PLANTS HARVESTED IN AUGUST 1969

Genus or species	Number	Mineral content (percentage of dry weight)					
		Ash	Nitrogen	Phosphorus	Calcium	Magnesium	Potassium
Scirpus	14	5.6(±.9)	1.10(±.13)	0.13(±.02)	0.53(±.09)	0.08(±.02)	1.09(±.18)
Chara	18	66.0(±4.1)	1.05(±.20)	0.15(±.04)	21.1(±3.5)	0.62(±.12)	0.57(±.15)
Typha	5	7.9(±3.3)	0.87(±.26)	0.10(±.06)	1.19(±.28)	0.18(±.11)	1.18(±.58)
Vallisneria	11	40.3(±10.3)	1.28(±.17)	0.14(±.02)	5.41(±1.82)	0.85(±.28)	1.85(±.36)
Zizania aquatica	6	17.5(±2.0)	1.23(±.16)	0.14(±.02)	1.86(±.58)	0.34(±.06)	1.64(±.16)
Elodea	4	30.3(±1.9)	1.44(±.23)	0.17(±.03)	7.23(±.74)	0.51(±.11)	1.18(±.31)
Potomageton illinoensis	2	25.3(±10.6)	1.43(±.18)	0.13(±.01)	6.32(±4.58)	0.50(±.11)	1.44(±.39)
Potomageton natans	1	17.4	1.55	0.15	2.59	0.60	1.73
Potomageton nodosus	1	17.4	1.30	0.14	4.84	0.67	1.23
Potomageton richardsonii	3	25.93(±4.2)	1.44(±.03)	0.14(±.01)	6.50(±1.19)	0.60(±.04)	1.09(±.02)

TABLE 6. ASH AND MACRONUTRIENT CONTENT OF SEVERAL AQUATIC PLANTS HARVESTED IN JUNE 1970

Genus or species	Number	Mineral content (percentage of dry weight)					
		Ash	Nitrogen	Phosphorus	Calcium	Magnesium	Potassium
Scirpus	16	5.4(±1.2)	1.28(±.17)	0.19(±.04)	0.44(±.23)	0.10(±.03)	1.43(±.37)
Chara	16	67.5(±2.3)	0.93(±.18)	0.13(±.03)	23.8(±1.0)	0.46(±.10)	0.64(±.06)
Typha	4	6.5(±1.1)	1.13(±.24)	0.12(±.02)	1.26(±.34)	0.19(±.12)	1.35(±.61)
Vallisnera	2	21.8(±3.4)	1.98(±.25)	0.22(±.01)	3.25(±1.06)	1.02(±.14)	2.15(±.14)
Zizania aquatica	1	11.5	1.75	0.18	1.50	0.31	2.00
Elodea	4	18.9(±2.7)	1.74(±.30)	0.22(±.03)	3.75(±1.58)	0.41(±.12)	2.94(±2.27)
Potomageton illinoensis	2	16.4(±4.3)	2.28(±.53)	0.20(±.04)	3.50(±.71)	0.48(±.04)	1.88(±.25)
Potomageton natans	1	13.3	2.45	0.22	2.09	0.67	1.77
Potomageton pectinatus	1	14.8	2.65	0.25	3.30	0.59	1.27
Potomageton richardsonii	5	14.5(±5.9)	1.81(±.37)	0.22(±.04)	3.90(±1.25)	0.50(±.16)	1.22(±.17)

Table 7. Ash and Macronutrient Content of Several Aquatic Plants Harvested in August 1970

Genus or species	Number	Mineral content (percentage of dry weight)					
		Ash	Nitrogen	Phosphorus	Calcium	Magnesium	Potassium
Scirpus	31	5.3(±1.0)	1.16(±.23)	0.13(±.02)	0.45(±.10)	0.07(±.03)	1.23(±.28)
Chara	17	69.1(±4.3)	0.98(±.12)	0.15(±.03)	25.1(±2.5)	0.50(±.09)	0.41(±.07)
Typha	8	5.5(±0.4)	1.19(±.54)	0.12(±.05)	1.19(±.18)	0.20(±.06)	0.98(±.49)
Vallisneria	3	30.9(±9.7)	1.55(±.13)	0.14(±.01)	5.20(±1.39)	1.52(±.48)	0.84(±.36)
Zizania aquatica	1	4.3	1.25	0.12	1.50	0.23	0.93
Elodea	4	29.1(±6.9)	1.55(±.12)	0.18(±.04)	6.95(±2.95)	0.70(±.06)	0.85(±.21)
Potomageton illinoensis	5	30.5(±6.3)	1.64(±.17)	0.13(±.01)	5.64(±1.15)	0.71(±.06)	0.66(±.10)
Potomageton natans	1	7.4	1.65	0.17	4.30	0.60	1.27
Potomageton richardsonii	1	6.2	1.95	0.23	7.60	0.82	0.88

per cent ash are fairly typical of emergent plants as well as of terrestrial plants in general. The ash content of these two species has been reported to be in the range of 2 to 10 per cent (Gorham, 1953; Mayer and Gorham, 1951). The ash content of the only other emergent, *Zizania aquatica*, was highly variable among sampling dates. This could have been the result of contamination from soil particles or it could have been caused by a variable silicon content since the total base content among samples was not greatly different.

For the submergent species listed in Tables 5, 6 and 7, the ash content ranged from about 12 to 40 per cent. Boyd (1968) noted a range of from 15 to 30 per cent in the ash content of the submergent species. Recorded values for *Elodea* include 19.8 per cent (Meyer and Gorham, 1951), 21.9 per cent (Nelson and Palmer, 1939) and 27.9 per cent (Gortner, 1934). For *Vallisneria*, they include 15.6 per cent (Nelson and Palmer, 1939), 20.7 per cent (Birge and Juday, 1922), 25.2 per cent (Schuette and Alder, 1927) and 28.6 per cent (Gortner, 1934). Values given for the potomagetons include 11.4 per cent (Schuette and Alder, 1927), 15.5 per cent (Mayer and Gorham, 1951) and 26.7 per cent (Birge and Juday, 1922). Thus, the values reported here are fairly consistent with the ash content of these plants as reported in earlier work.

Nitrogen and Phosphorus Content The nitrogen content of the plants harvested from these marshes ranged from slightly less than 1 per cent to slightly more than 2.5 per cent, in most cases being from 1 to 2 per cent. In addition, there was relatively little difference for the same species in 1970 between the samples taken in June and those taken in August. Boyd (1968) reported that the nitrogen content of submerged species was generally from 3 to 4 per cent while the emergent species usually contained less than 2.5 per cent. This difference was not apparent in our data.

Gerloff and Krombholz (1966) reported a critical nitrogen concentration of 1.3 per cent for several aquatic species. They reported values of from 2.1 to 3 per cent for *Elodea* and from 1.9 to 3.7 per cent for *Potomageton richardsonii* found in several Wisconsin lakes. From their values, they concluded that nitrogen was probably not limiting in these lakes. Birge and Juday (1922) reported *Potomageton* and *Vallisneria* from Wisconsin lakes to contain 1.47 and 2.80 per cent of nitrogen, respectively. Later Schuette and Alder (1927) analyzed these same two species and found concentrations of 1.3 per cent for *Potomageton* and 1.9 per cent for *Vallisneria*. *Elodea* and *Vallisneria* taken from Minnesota lakes contained 4.3 and 2.4 per cent, respectively (Nelson and Palmer, 1939). Gortner (1934) reported nitrogen contents of 1.9, 2.4 and 3.0 per cent, respectively, for *Elodea*,

Vallisneria and *Potomageton pectinatus*. Harper and Daniel (1934) found values ranging from 1.4 to 2.5 per cent for several aquatic species.

The nitrogen content of *Chara* has been found to be quiet variable with values of 0.84 per cent (Gortner, 1934), 0.72 per cent (Schuette and Alder, 1929) and 2.46 per cent (Boyd and Lawrence, 1966) being reported. Our values were more nearly comparable to the earlier records than to those reported by Boyd and Lawrence.

Fewer data are available for the emergent aquatic plants. Gorham (1953) reported nitrogen contents of 2.69 per cent for *Typha* and 2.06 per cent for *Scirpus*. Boyd (1968) gave a value of 1.59 per cent for *Typha*. These values are slightly higher than those found in the present study.

Based on the analyses of *Chara* and *Scirpus* in the shallow marshes, something on the order of 90 to 100 kilograms of nitrogen per hectare were present in the vegetation, while in the deepest marshes no more than 25 to 30 kilograms per hectare were found. Since the nitrogen input in these marshes was undoubtedly fairly uniform, it does not appear that the fairly uniform nitrogen content of the vegetation could be attributed to nitrogen deficiency in the system. In addition, the nitrogen supply could not be limiting growth in the deeper marshes.

The phosphorus content of the species found in the marshes varied from 0.25 to 0.1 per cent with most of the values falling in the range of 0.12 and 0.20 per cent. Thus, most of the values reported were at or above the critical value of 0.13 per cent determined by Gerloff and Krombholz (1966). In every instance, however, the average phosphorus content of *Typha* was slightly below the critical value of Gerloff and Krombholz. This was the only species with a phosphorus content below 0.13 per cent.

Schuette and Alder (1929) reported a phosphorus content for *Chara* of 0.06 per cent, while Forsberg (1960) gave a value of 0.1 per cent. On the other hand, Boyd and Lawrence (1966) found a value of 0.25 per cent. Our values of 0.13 and 0.15 per cent fell between those previously reported.

The phosphorus content of submerged species other than *Chara* ranges from 0.12 per cent for *Elodea* (Gerloff and Krombholz, 1966) to about 0.6 per cent for both *Elodea* (Nelson and Palmer, 1939) and *Potomageton richardsonii* (Gerloff and Krombholz, 1966). Values in the range of 0.2 per cent appear usual (Harper and Daniel, 1934) and are typical of our measurements.

In the shallow marshes, about 12 to 14 kilograms of phosphorus per hectare were present in the vegetation, largely accounted for by the emergents. In the 3-foot-deep marshes, about 4 to 5 kilograms per

hectare were contained in the vegetation. As with nitrogen, there seems to be no particular concentrating of the phosphorus in the submerged vegetation, and it seems probable that phosphorus was not limiting growth in the deeper marshes.

Calcium, Magnesium and Potassium Content The most notable feature of the calcium content was its very low level in *Scirpus* and its very high level in *Chara*. The values for *Chara* reported here are close to those given by others, i.e., 24.6 per cent (Nelson and Palmer, 1939), 27 per cent (Schuette and Alder, 1929) and 17 to 24 per cent (Forsberg, 1960). However, the value of 9.03 per cent given by Boyd and Lawrence (1966) is substantially lower than any other reported value. Most of the calcium associated with *Chara* is present as calcium carbonate ($CaCO_3$), and this accounts for the extremely high ash content of this alga. Based on the calcium content of the *Chara* in our studies, if it were all present as $CaCO_3$ it would comprise about 60 per cent of the dry weight of the plants. This is a reasonable estimate based on the ash content. The total quantity of calcium associated with the standing crop of *Chara* ranges from about 380 to 520 kilograms per hectare. Thus, *Chara* provides a considerable sink for calcium particularly in alkaline waters.

The calcium content of the other submerged species in these marshes ranged from about 3 to 7 per cent. Usually the calcium content of the samples taken in August was higher than that of those taken in June. In *Elodea*, for example, it rose from 3.75 per cent in June to 6.95 per cent in August. *Vallisneria* and *Potomageton* showed the same trend. In these species, however, the high content of ash could not be accounted for by considering the calcium to be present as $CaCO_3$; this would account for only about half the total ash. Although no analyses were made, the only possibility that seems reasonable is that these species accumulated large quantities of silicon. The few analyses for silicon available (Schuette and Alder, 1927; Forsberg, 1960), however, cast some doubt on this possibility.

The calcium values reported here for the submerged species in general are slightly higher than other reported values, although Harper and Daniel (1934) reported 8 to over 10 per cent for *Elodea*. Nelson and Palmer (1939) reported 2.80 per cent for *Elodea* and 1.55 per cent for *Vallisneria*. Schuette and Alder (1927), on the other hand, found values of 5.1 per cent for *Vallisneria* and 2.1 per cent for a potomageton.

The low calcium content of about 0.5 per cent for emergent *Scirpus* has already been noted. The values for both *Typha* and *Zizania aquatica* were in the range usually found in terrestrial plants, i.e., between 1 and 2 per cent. Boyd (1968) reported 1.48 per cent for *Typha*, while

Harper and Daniel (1934) gave values of about 0.4 per cent. With little to compare our values with, it can be concluded only that they appear reasonable.

There was a wide range in the magnesium content of the species found in the marshes. *Scirpus* is again notable with its extremely low content compared with other species present. The magnesium content of *Typha* was also low relative to that of other species although it was at least double the content of *Scirpus*. The quantity found in other species, from about 0.4 per cent to over 1 per cent in *Vallisneria,* is fairly typical of other reported values. Nelson and Palmer (1939) gave 0.65 per cent for *Elodea* and 0.76 per cent for *Vallisneria*. The value of 1.12 per cent for *Vallisneria* reported by Schuette and Alder (1927) compares with the values found in the present study. They also found the magnesium content of the potomagetons to be 0.8 per cent which is in the range of our values also. For *Chara,* values reported include 0.71 per cent (Schuette and Alder, 1929; Nelson and Palmer, 1939) and 0.5 to 0.6 per cent (Forsberg, 1960). Thus, while the calcium content of *Chara* is extremely high, the magnesium content is in the normal range of most plant materials.

The potassium content of the species found in these marshes was within normal ranges except for that of *Chara* which was relatively low. Schuette and Alder (1929) reported a value of 0.48 per cent which is essentially the same as that for our *Chara* samples. Boyd and Lawrence (1966), on the other hand, reported an average of 2.35 per cent for 59 samples of *Chara*. The highest value for 51 samples in the present study was 0.84 per cent so that we found nothing close to the values reported by Boyd and Lawrence.

Schuette and Alder (1927) found a potassium content of 4.5 per cent in *Vallisneria,* and Nelson and Palmer (1939) reported a value of 6.77 per cent. These values are higher than those found in the present study. A potassium content of 3.65 per cent for *Elodea* was given by Nelson and Palmer (1939). For the potomagetons analyzed by Schuette and Alder (1927) a content of 1.7 per cent was reported. These values are about the same or slightly higher than those we found. As Boyd (1968) concluded, the potassium content of the macrophytes can be extremely variable.

Iron and Manganese The iron and manganese content of the plant samples removed from the marshes is given in Table 8. In general, the results were quite variable as shown by the standard deviations about the means. The two emergent plants, *Scirpus* and *Typha,* had a lower content of both iron and manganese than did the submergent species. Although fewer samples were involved, *Zizania aquatica* had an iron content more nearly comparable to that of the

submergents while the manganese content was more nearly comparable to that of *Scirpus* and *Typha*. Mayer and Gorham (1951) reported iron values for *Scirpus* of 210 ppm compared with our values of 295 to 560 ppm. Their value for manganese was 430 ppm compared with our values of 855 to 950 ppm. The iron content of *Typha* found by Mayer and Gorham (1951) was from 190 to 320 ppm compared with 800 to 1,730 ppm found in our samples. They reported the manganese content of *Typha* at 600 to 870 ppm compared with our values of 612 to 724 ppm.

Considering *Chara*, Boyd and Lawrence (1966) reported the iron content to average 2,520 ppm which is very close to our values. They reported a manganese value of 2,926 ppm which is about double what we found. The iron and manganese contents of *Chara* reported by Schuette and Alder (1929) were 420 and 540 ppm, respectively, which are substantially lower than either our values or those of Boyd and Lawrence.

The iron content of *Vallisneria* was highly variable in our samples, with the sample taken August 1969 being extremely high at 12,309 ppm. The manganese content of about 2,000 ppm, on the other hand, was not greatly different from that of other species and was not highly variable from one sampling time to another. Schuetter and Alder (1927) found the iron content to be 3,840 ppm. Nelson and Palmer (1938) reported much lower levels of both iron and manganese in *Vallisneria*, i.e., 450 ppm and 390 ppm, respectively. In the potomagetons, Schuette and Alder (1927) gave values of 770 ppm for iron and 540 ppm for manganese, while Mayer and Gorham (1951) gave values of from 820 to 1,320 ppm and from 700 to 2,440 ppm, respectively. Our values ranged from about 2,000 to 7,000 ppm of iron in the various potomagetons and from about 1,000 to over 3,000 ppm of manganese in the same samples.

In *Elodea*, Mayer and Gorham (1951) found 1,320 ppm of iron and 2,240 ppm of manganese, while Nelson and Palmer (1938) reported values of 4,080 and 3,310 ppm, respectively. Our values of from 4,000 to over 7,000 ppm of iron in *Elodea* were somewhat higher than those reported previously. The manganese content of from 200 to 3,000 ppm in our samples was about that found in the earlier results.

Our evidence and that found in other reports indicates that both the iron and manganese contents of these aquatic species are highly variable. Boyd (1968) concluded that both are subject to considerable interspecific variation and intraspecific variation. Our results bear out this conclusion. In general, the emergent vegetation was lower in iron and manganese than the submerged species. Mayer and Gorham (1951) observed that the aquatic species contained higher quantities of both

TABLE 8. IRON AND MANGANESE CONTENT OF SEVERAL AQUATIC PLANTS

Genus or species	Iron (ppm)			Manganese (ppm)		
	August 1969	June 1970	August 1970	August 1969	June 1970	August 1970
Scirpus	295(±165)	563(±705)	308(±197)	922(±306)	956(±333)	855(±304)
Chara	2,535(±1211)	2,783(±1097)	2,785(±926)	1,975(±1513)	1,373(±386)	1,205(±700)
Typha	1,731(±1870)	972(±1196)	801(±1237)	651(±590)	612(±519)	724(±266)
Vallisneria	12,309(±3253)	2,970(±1541)	7,567(±379)	2,085(±886)	1,920(±311)	2,700(±721)
Zizania aquatica	4,840(±466)	2,520	2,300	823(±323)	1,030	790
Elodea	4,317(±2722)	4,135(±451)	7,125(±2380)	2,208(±990)	2,545(±654)	2,925(±556)
Potomageton illinoensis	3,972(±342)	1,862(±1467)	6,860(±1618)	1,172(±910)	890(±552)	2,600(±860)
Potomageton natans	3,250	2,740	5,700	1,705	1,500	3,700
Potomageton nodosus	2,200	..	..	1,023	..	..
Potomageton pectinatus	..	2,140	..	..	1,040	..
Potomageton richardsonii	2,218(±193)	1,974(±2188)	6,900	1,423(±108)	1,262(±336)	1,200

these metals than did typical terrestrial plants. Our results support this observation.

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CHANGES IN WATER CHEMISTRY IN MARSHES OVER A 12-YEAR PERIOD FOLLOWING ESTABLISHMENT[1]

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ABSTRACT

Changes in water chemistry (pH, oxygen and alkalinity) were measured over a 12-year period following establishment in 20 artificial marshes varying in depth from 1 to 3 feet by ½-foot intervals. The partial pressure of carbon dioxide in the water (calculated from alkalinity and pH) was usually less than atmospheric during the initial 7 years, but during the last 5 years the water was usually supersaturated with respect to the atmosphere. Changes in alkalinity over time were consistent with those expected if the water tended toward equilibrium with calcium carbonate and dissolved carbon dioxide. The change in carbon dioxide content of the water was related to changes in vegetation in the following way. During the initial 7 years, the major macrophytic vegetation was submerged, and the source of carbon for this vegetation was inorganic carbon in the water. Rate of fixation by photosynthesis apparently exceeded the rate of supply across the air-water interface and decomposition of organic matter. During the last 5 years, emergent macrophytes dominated some marshes. These plants derived their carbon from the air, but fell into the water during the winter. During the summer, decay of this vegetation exceeded the capacity of the submerged vegetation to fix inorganic carbon and, hence, carbon dioxide accumulated in excess of that in the atmosphere.

In a previous publication (Lathwell et al., 1969), the plant growth and chemical changes that occurred in 20 artificial marshes during the initial 7 years following establishment were summarized. Measurements have been continued through 1971. The objective of this paper is to summarize and describe some of the changes in water chemistry that have occurred over a 12-year period following establishment. In another paper, Lathwell et al. (1973) describe the vegetation changes and the composition of the vegetation.

METHODS AND MATERIALS

The details of the marsh establishment and the treatments applied were described by Lathwell et al. (1969). During 1961 through 1965, water samples were taken at approximately 7- to 10-day intervals during the months of June, July and August. These samples were taken

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at 6-inch depth intervals in the individual marshes by means of a pump. Since, in general, there was no thermal stratification, the water samples taken at different depths within one marsh at a common sampling time were all very similar; the results were averaged to obtain one value for each marsh for each sampling date. The marshes were sampled at random throughout the day, and the time of sampling, which usually varied from 8:00 a.m. to 4:00 p.m. for any given sampling date, was recorded.

Over the period 1966 through 1971, the sampling schedule was revised considerably and varied from year to year. Only one water sample was taken from each marsh at a given sampling time. The sampling interval during the summer was not so frequent as in previous years, but samples were taken during other seasons of the year. All samples were taken at 8:00 a.m. local time during this period.

The temperature of the sample was determined with a thermometer within 5 minutes of removal from the marsh, and its pH was determined with a Beckman model G pH meter within about 30 minutes. Alkalinity was determined to the methyl orange end point with standard acid. Dissolved oxygen was determined by the Winkler procedure.

By definition, alkalinity is the amount of acid required to titrate a water sample to pH 4.6. In most fresh water, the alkalinity is essentially equal to the acid required to convert HCO_3^- and $CO_3^=$ to H_2CO_3. The relationship between CO_2 and H_2CO_3 in solution, HCO_3^- and $CO_3^=$ are well known functions of pH. Therefore, alkalinity and pH can be used to calculate the amount of inorganic carbon in solution $(CO_2 + H_2CO_3 + HCO_3^- + CO_3^=)$. In addition, these same parameters can be used to calculate the amount of $CO_2 + H_2CO_3$ in solution relative to the amount expected if the solution is in equilibrium with the carbon dioxide (CO_2) in the atmosphere. The interested reader may find a complete discussion of these relationships in Garrels and Christ (1965). The parameters total inorganic carbon in solution and relative saturation of the water with respect to atmospheric carbon dioxide were used in the analysis of the data, and these parameters were calculated as follows.

Total inorganic carbon in the water samples was calculated using Equation (1)

$$C_T = A \frac{F_2}{F_1} \qquad (1)$$

where C_T = total inorganic carbon in micromoles per liter

$= (CO_2 + H_2CO_3 + HCO_3^- + CO_3^=)$

A = alkalinity in microequivalents per liter

$$F_2 = 1 + \frac{K_1}{Y_1 H} + \frac{K_1 K_2}{Y_2 H^2}$$

$$F_1 = \frac{K_1}{Y_1 H} + 2\,\frac{K_1 K_2}{Y_2 H^2}$$

H = activity of H^+

K_1 = first dissociation constant of carbonic acid = $10^{-6.8}$

K_2 = second dissociation constant of carbonic acid = $10^{-10.30}$

Y_1 = activity coefficient of the HCO_3 ion which for these calculation was set to equal 0.95

Y_2 = activity coefficient of the CO_3^- ion which for these calculations was set equal to 0.80

The concentration of $CO_2 + H_2CO_3$ in solution relative to the amount expected if the water were in equilibrium with the normal atmosphere (with a partial pressure of $CO_2 = 10^{-3.50}$ atmospheres) was calculated using Equation (2).

$$S = \frac{A}{(F_1)\ (10^{-4.97})} \qquad (2)$$

where S = relative saturation of the water with respect to atmospheric carbon dioxide

$10^{-4.97}$ = expected concentration of $CO_2 + H_2CO_3$ in water in equilibrium with the atmosphere

Solar radiation records were taken from a weather station about 5 miles from the marsh area. Stepwise regressions of oxygen shown in Table 1 were calculated with the data grouped to obtain one regression for all depths each year and one regression for each depth each year.

RESULTS

The results are presented under the several following topic.

Correlations Among Variables

The results of the stepwise regression analysis were generally ambiguous except in the case of oxygen content and hour of sampling. In all cases, the oxygen content of the sample was well correlated with hour of sampling, and regressions of oxygen on hour of sampling were used to correct the oxygen to 8:00 a.m. values.

Shown in Table 2 are the means and standard deviations of the means of selected variables for the period 1961 through 1965, and Table 3 lists the correlation coefficients between oxygen and selected variables. The consistent correlation between oxygen and hour of sampling is one noteworthy point and was, of course, expected. Another

TABLE 1. INDEPENDENT VARIABLES USED IN STEPWISE REGRESSION ANALYSIS OF OXYGEN AND INORGANIC CARBON

Variable	Symbol
Hour of sampling	H
Hour of sampling squared	H^2
Depth of marsh	D
Temperature of water	T
Radiation, day of sampling	R1
Radiation, day previous to sampling	R2
Days after June 1	J
Days after June 1 squared	J^2
Depth of marsh × hour of sampling	D × H
Depth of marsh × days since June 1	D × J
Hour of sampling × radiation, day of sampling	H × R1

TABLE 2. MEANS AND STANDARD DEVIATIONS OF VARIABLES FOR THE PERIOD 1961 TO 1965

Variable	1961	1962	1963	1964	1965
Inorganic carbon*	1558 ± 321	1047 ± 312	838 ± 225	1001 ± 249	601 ± 208
Oxygen*	282 ± 46	272 ± 39	295 ± 46	278 ± 52	278 ± 60
Hour of sampling	12 ± 2	13 ± 2	12 ± 2	12 ± 2	12 ± 2
Solar radiation§	491 ± 169	534 ± 158	524 ± 136	510 ± 134	453 ± 142
Days from June 1	62 ± 23	55 ± 27	47 ± 26	59 ± 30	60 ± 30
Water temperature	24 ± 2	22 ± 2	22 ± 4	22 ± 4	22 ± 4

* In micromoles per liter.
§ In gram calories per square centimeter per day.

TABLE 3. CORRELATIONS BETWEEN OXYGEN CONTENT AND SELECTED VARIABLES

Variables	Correlation coefficient				
	1961	1962	1963	1964	1965
Oxygen and hour of sampling	0.45	0.63	0.66	0.72	0.72
Oxygen and radiation the day of sampling	−0.01	0.06	0.18	0.26	−0.03
Oxygen and days from June 1	0.08	0.33	0.46	−0.09	0.16
Oxygen and water temperature	0.08	0.12	0.31	0.02	0.09
Oxygen and depth of marsh	−0.04	−0.13	−0.07	−0.03	−0.20
Oxygen and pH	−0.18	0.40	0.59	0.41	0.28
Correlation coefficient at 5% probability level	0.14	0.12	0.12	0.11	0.12

TABLE 4. CORRELATIONS BETWEEN INORGANIC CARBON CONTENT AND SELECTED VARIABLES

Variables	1961	1962	1963	1964	1965
Inorganic carbon and hour of sampling	−0.14	0.02	−0.20	−0.06	−0.01
Inorganic carbon and radiation day of sampling	0.10	0.00	0.22	−0.03	−0.03
Inorganic carbon and days from June 1	−0.21	−0.17	−0.58	−0.06	−0.15
Inorganic carbon and water temperature	0.03	0.12	−0.14	−0.01	−0.02
Inorganic carbon and depth of marsh	0.11	0.02	−0.04	−0.38	−0.42
Inorganic carbon and oxygen	−0.37	−0.37	−0.47	−0.24	−0.07
Correlation coefficient at 5% probability level	0.14	0.12	0.12	0.11	0.12

noteworthy and unexpected result was the generally poor correlation between radiation and oxygen content. There is no evidence that oxygen content was consistently correlated with solar radiation even though there was considerable variation in solar radiation among sampling days (see Table 2).

Table 4 lists the correlations between inorganic carbon and selected variables. Rather surprisingly, inorganic carbon was not consistently correlated with any of the variables. Hour of sampling and solar radiation of the day of sampling is not of much importance. Generally the inorganic carbon decreases as the season progresses as evidenced by the negative correlation with days from June 1. In the later years, the depth of marsh was negatively correlated with inorganic carbon, and this will be dealt with in more detail in subsequent topics. There was generally a negative correlation between inorganic carbon and oxygen content during the early years, but this correlation was very poor during the last year shown in Table 4 (1965).

The correlations for the period 1966 to 1971 were generally similar to those shown in Tables 3 and 4; they are not presented here since they do not contain the hour of sampling variable and they add nothing of importance to the present discussion.

WATER CHEMISTRY FOR SUMMER MONTHS DURING PERIOD 1961-1971

Shown in Figure 1 are the average concentrations of inorganic carbon and oxygen for June, July and August plotted against years. The oxygen values are adjusted to 8:00 a.m. by regressions of oxygen on hour of sampling for the 1961-1966 period. The values of inorganic carbon (C_T) were usually not significantly influenced by hour of sampling, so that values shown are simple averages. Inorganic carbon decreased initially during the interval 1961 to 1965 and since then has increased rather rapidly. Oxygen at 8:00 a.m. did not change appre-

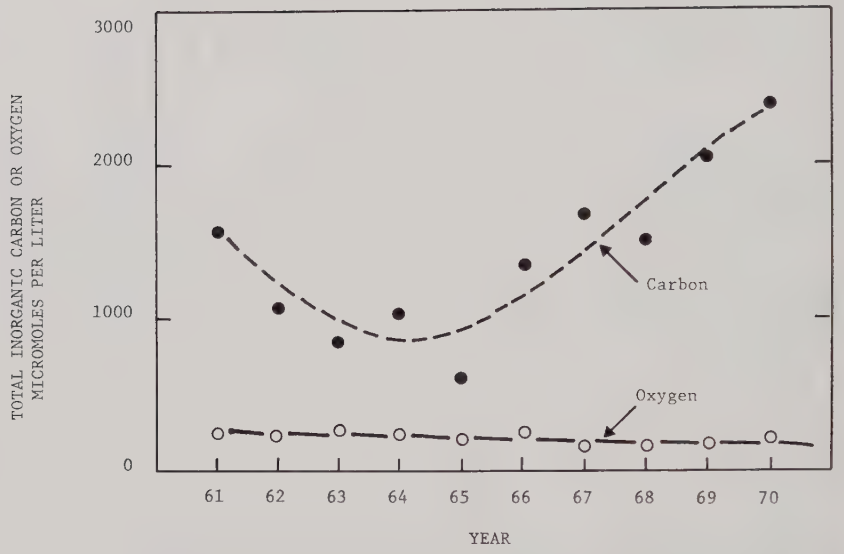

Figure 1. Average inorganic carbon and oxygen contents (8:00 a.m.) during summer months plotted against year. Points are experimental observations, lines are drawn visually for reference purposes.

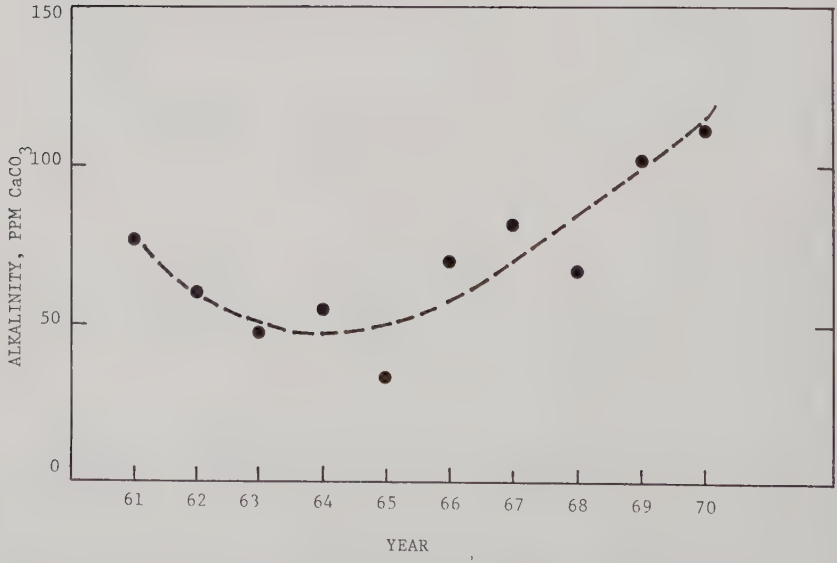

Figure 2. Average alkalinity (June, July and August) plotted against year.

ciably although there has been a slight trend toward lower values as the marshes have aged.

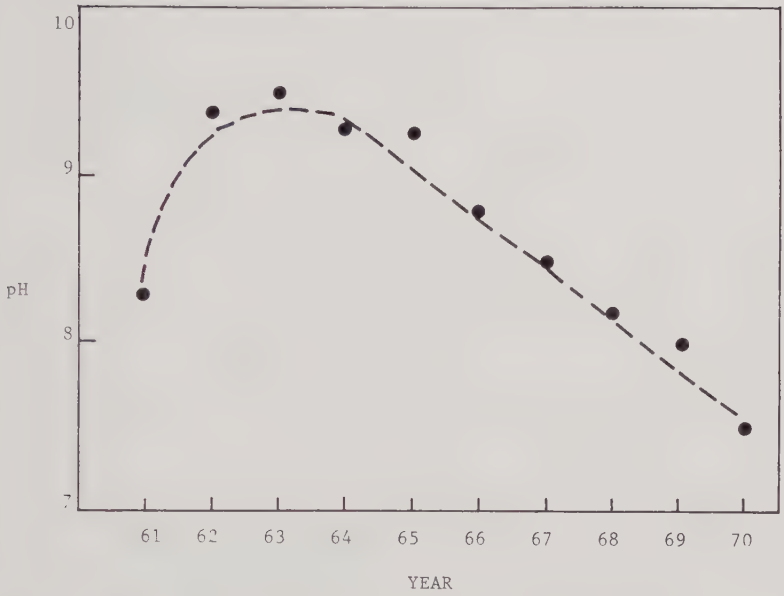

Figure 3. Average pH values during summer months plotted against year. The 1961 to 1965 samples were taken throughout the day, while the 1966 to 1970 samples were taken at 8:00 a.m. Points are experimental observations, line is drawn in visually for reference purposes.

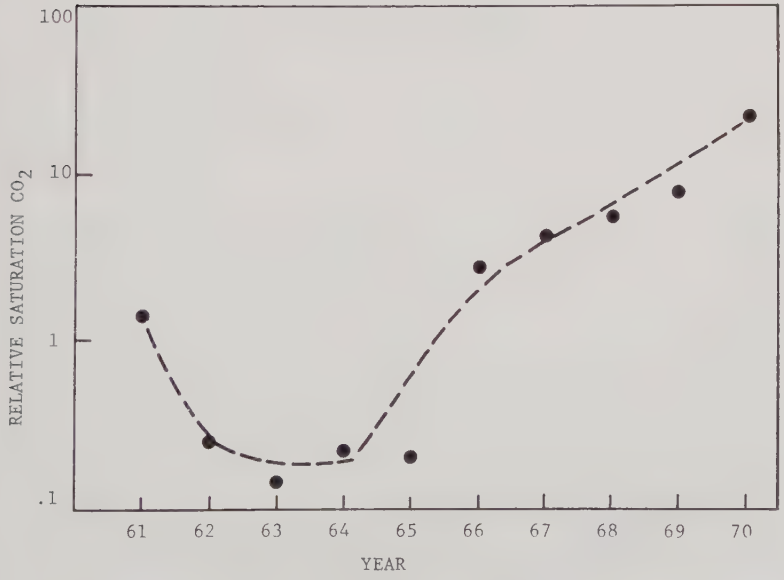

Figure 4. Calculated activity of carbon dioxide in water relative to atmospheric carbon dioxide during summer months plotted against year. Points are experimental observations, line is drawn in visually for reference purposes.

Since total inorganic carbon is a function of alkalinity, pH and the degree of saturation with respect to atmospheric carbon dioxide, the changes in these parameters over years is examined in the succeeding sentences. The alkalinity changes paralled those of inorganic carbon as shown in Figure 2. The pH values have undergone an inverse change, i.e., an increase followed by a decrease as illustrated in Figure 3. Finally, the relative saturation with respect to atmospheric carbon dioxide has undergone marked changes as illustrated in Figure 4 (note log scale).

The sediments in the marshes are calcareous, and the *Chara* was about 50 per cent calcium carbonate ($CaCO_3$) on a dry weight basis. Therefore, the changes in alkalinity and pH over years may well have been a consequence of changing partial pressure of carbon dioxide in the water and equilibration of the water with calcium carbonate. This hypothesis is examined in Figure 5 where alkalinity is plotted against the partial pressure of carbon dioxide in the water. The line in Figure 5 represents the model system of solutions in equilibrium with pure calcite in water. Note that in this model system alkalinity is equal to the calcium concentration in the water. The circles represent the partial pressure of carbon dioxide and alkalinity averaged over the months of June, July and August for the period 1961-71. The data points are moderately consistent with the CO_2-$CaCO_3$ model, and the general trend of the results indicates that the water chemistry is strongly influenced by the chemistry of the CO_2-$CaCO_3$ equilibrium. The evidence in Figures 4 and 5 illustrates that the marshes were usually not close to equilibrium with atmospheric carbon dioxide, indicating that sinks and sources of carbon dioxide within the water were more important than the atmosphere in influencing the carbon dioxide content of the water.

Several factors lead to deviations of the observed water chemistry from the ideal situation represented by the line in Figure 5 for the CO_2-$CaCO_3$ system. First, the equilibration of solid phase calcium carbonate with the water is a slow process, and the diurnal shifts in pH (which are between ½ and 1 pH unit) would require the dissolution and precipitation of large amounts of calcium carbonate diurnally to maintain equilibrium between it and the water. In the pH range observed here, addition or removal of a small amount of carbon dioxide to the solution results in a large shift in pH. In the early morning, the pH was low and the solutions were often undersaturated with respect to calcium carbonate while by afternoon the pH had increased enough so that the solutions were supersaturated. By and large, the changes in total inorganic carbon were not large, but the fraction of total inorganic carbon in the $CO_3^=$ form often changed by

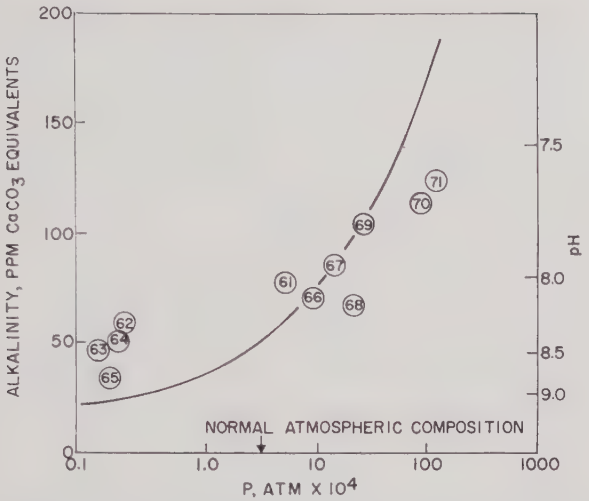

Figure 5. Average alkalinity plotted against average partial pressure of carbon dioxide in the water for the months of June, July and August from 1961 to 1971. The solid line represents the relationship expected if calcite is in equilibrium with different partial pressures of cabon dioxide. The numbers inside the circles are the last two digits of the corresponding year.

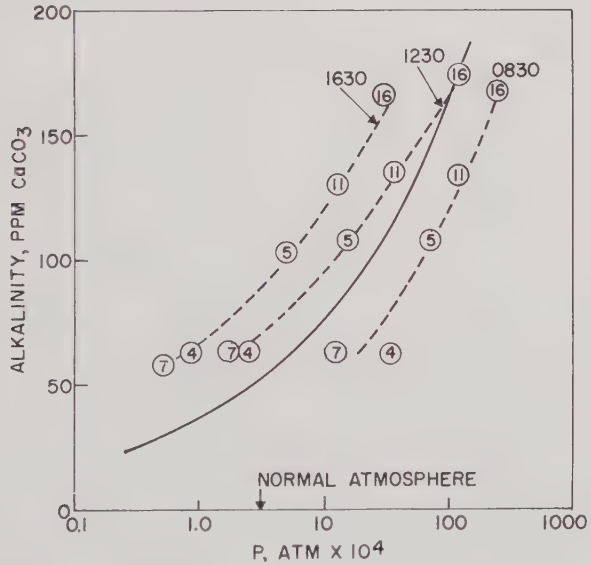

Figure 6. Alkalinity of water plotted against partial pressure of carbon dioxide in the water for five selected marshes at different times on July 22, 1971. The solid line represents solutions in equilibrium with calcite, the dashed lines are drawn through samples taken at a given time for purposes of comparison. The circles are experimental observations and the numbers inside the circles are marsh indentification numbers. Marshes 4 and 7 were 2.5 feet deep, 5 was 3 feet deep, 11 was 2 feet deep and 16 was 1.5 feet deep.

an order of magnitude from early morning to late afternoon as a consequence of the pH change. Figure 6 illustrates the diurnal variation in five marshes for July 22, 1971. The five marshes selected cover the range of alkalinities, and illustrate the diurnal variation in saturation with respect to calcium carbonate. Thus, the kinetics of calcium carbonate dissolution and precipitation appear to be too slow for the water to be in equilibrium with it unless biological processes are slow enough so that major changes in pH do not occur.

Figure 6 also illustrates the results shown in Figure 5; that is, the lower the partial pressure of carbon dioxide, the lower the alkalinity, which is in agreement with the hypothesis stated previously.

A second reason for deviation of the water chemistry from the CO_2-$CaCO_3$ model is that the water in the marshes contained ions other than those associated with calcium carbonate and, as a consequence, alkalinity was not necessarily equal to the equivalents of calcium in solution. The relationship between equivalents of calcium in solution and alkalinity is illustrated in Figure 7 for water samples taken June 16 and August 17 in 1971. The concentrations of cations are listed in Table 5. In general, there was a reasonable relationship between the two variables, alkalinity and calcium, but there was enough

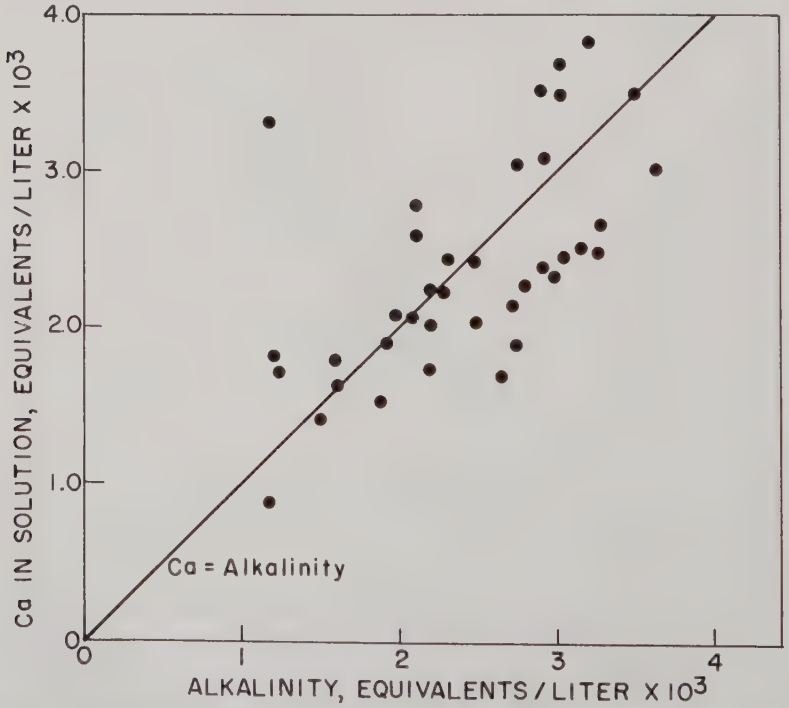

Figure 7. Calcium in solution plotted against alkalinity for water samples taken at 8:00 a.m. on June 16 and at 2:00 p.m. on August 17 in 1971.

TABLE 5. CATION CONTENTS AND ALKALINITY OF WATER SAMPLES TAKEN AT 8:00 A.M. ON JUNE 16 AND AT 2:00 P.M. ON AUGUST 17 IN 1971

Marsh No.*	Moles per liter × 10^3				Alkalinity (equivalent per liter × 10^3)
	Calcium	Magnesium	Sodium	Potassium	
			June 16		
1	1.01	0.22	0.06	0.02	2.5
2	0.77	0.24	0.05	0.02	1.9
3	1.34	0.22	0.02	0.02	3.3
4	1.04	0.20	0.03	0.01	2.1
5	0.88	0.22	0.02	0.01	2.2
6	1.25	0.25	0.01	0.01	3.3
7	0.94	0.21	0.02	0.02	1.9
8	1.50	0.20	0.02	0.01	3.6
9	0.46	0.22	0.02	0.01	1.2
11	1.14	0.22	0.03	0.02	2.8
12	1.08	0.22	0.03	0.02	2.7
13	1.25	0.22	0.04	0.01	3.2
14	1.25	0.22	0.04	0.02	3.2
15	1.21	0.22	0.03	0.01	2.3
16	1.20	0.24	0.02	0.01	2.9
17	1.02	0.28	0.08	0.02	2.1
18	1.20	0.21	0.03	0.02	2.9
19	0.90	0.27	0.04	0.01	1.2
20	0.88	0.25	0.04	0.01	1.2
			August 17		
1	1.30	0.30	0.060	0.0004	2.3
2	0.95	0.26	0.010	0.0001	2.7
3	1.55	0.30	0.054	0.0007	2.7
4	0.70	0.26	0.017	0.0002	1.5
5	1.13	0.26	0.048	0.0003	2.2
6	1.30	0.30	0.063	0.0007	2.2
7	0.90	0.30	0.039	0.0002	1.6
8	1.92	0.26	0.024	0.0002	3.2
9	1.65	0.31	0.070	0.0008	1.2
11	0.86	0.26	0.026	0.0002	2.6
12	1.75	0.31	0.058	0.0008	3.0
13	1.84	0.30	0.060	0.0006	3.0
14	1.75	0.30	0.060	0.0009	2.9
15	1.39	0.30	0.054	0.0004	2.1
16	1.55	0.30	0.035	0.0004	2.9
17	1.05	0.28	0.029	0.0002	1.6
18	1.75	0.22	0.030	0.0009	3.3
19	1.05	0.28	0.033	0.0005	2.1
20	1.22	0.30	0.039	0.0002	2.4

* Marsh No. 10 was dry because of a leaky berm.

variation in the relationship to account for appreciable deviations from the model system. Unfortunately, data on cation composition of the water were not collected prior to 1971.

In spite of considerable deviation from the ideal model, the water chemistry appears to be basically dominated by the $CaCO_3$-CO_2 (or

$CaCO_3$-inorganic carbon system). In the period 1961 to 1965, the partial pressure of carbon dioxide was less than atmospheric, inorganic carbon was relatively low, alkalinity was relatively low, and the pH was high. Since 1965 the partial pressure of carbon dioxide and inorganic carbon in the water have been steadily increasing, which has led to increased alkalinity and lower pH values as would be expected if calcium carbonate were a dominant factor. The changes in inorganic carbon and carbon dioxide resulting from photosynthesis, respiration, and interchange across the air-water interface are more rapid than the kinetics of dissolution and precipitation of calcium carbonate so that the pH and alkalinity are more a reflection of past levels of carbon dioxide and inorganic carbon than current levels.

The key variable which emerges from the foregoing discussion is the inorganic carbon in the water. Solid phase calcium carbonate is abundant both in the unamended sediments and in the 10 marshes to which limestone was added. Hence, variation in water chemistry among marshes and with time should be primarily dependent upon sources and sinks for inorganic carbon.

The two major factors influencing inorganic carbon appear to be photosynthesis and respiration with the interchange across the air-water interface being of only secondary importance.

In the next several paragraphs we will develop the hypothesis that the major driving force for the marked changes that have occurred since 1965 are a consequence of the establishment and proliferation of emergent vegetation. The dry matter production of emergent vegetation per unit of surface area is generally 2 to 6 times that of submerged plants. The emergent vegetation derives its carbon directly from the air, while the submerged vegetation derives its carbon from the water. As evidenced by Figure 4, the carbon dioxide in the water is not often at equilibrium with that in the atmosphere. In the period 1961 to 1965 few emergents were growing in the marshes. During the summer months in this period, consumption of inorganic carbon by photosynthesis generally exceeded production of inorganic carbon from decomposition of organic matter because only limited dry matter had been produced by the submerged vegetation the preceding summer. In the period 1965 to 1971, emergents dominated some marshes (particularly the shallow marshes). During winter the emergents generally fell into the water, and during the spring and following summer their decomposition furnished large quantities of inorganic carbon. In fact, production of inorganic carbon far exceeded consumption by photosynthesis in the submerged vegetation.

The evidence to support this hypothesis is in part qualitative and in part quantitative. Visual observations were made in the period 1961 to the fall of 1967. Since 1968, quantitative determinations of dry

TABLE 6. CORRELATION MATRIX AMONG TOTAL INORGANIC CARBON IN WATER SAMPLES AND DRY WEIGHT MEASUREMENTS

	Total inorganic carbon*					Total dry weight§					Dry weight, emergent§			
Factor	C_T66	C_T67	C_T68	C_T69	C_T70	J68	J69	A69	J70	A70	J69	A69	J70	A70
C_T66	1.00	0.96	0.88	0.74	0.72	0.74	0.72	0.83	0.76	0.78	0.77	0.86	0.80	0.80
C_T67		1.00	0.93	0.74	0.72	0.72	0.70	0.87	0.75	0.87	0.73	0.89	0.77	0.85
C_T68			1.00	0.85	0.84	0.84	0.79	0.88	0.87	0.90	0.81	0.90	0.88	0.91
C_T69				1.00	0.86	0.91	0.80	0.82	0.92	0.82	0.83	0.86	0.94	0.87
C_T70					1.00	0.88	0.90	0.80	0.83	0.84	0.90	0.82	0.86	0.94
D.W. J68						1.00	0.86	0.78	0.89	0.78	0.84	0.82	0.92	0.85
J69							1.00	0.84	0.85	0.82	0.95	0.82	0.87	0.88
A69								1.00	0.79	0.93	0.84	0.98	0.80	0.91
J70									1.00	0.83	0.84	0.80	0.96	0.86
A70										1.00	0.82	0.91	0.81	0.96
Emer. J69											1.00	0.86	0.91	0.89
A69												1.00	0.84	0.91
J70													1.00	0.86

* Designations (C_T66, etc.) represent the several years as indicated by the numerals in each case.
§ Designations (J68, etc.) represent June or August of the several years as indicated by the numerals in each case.

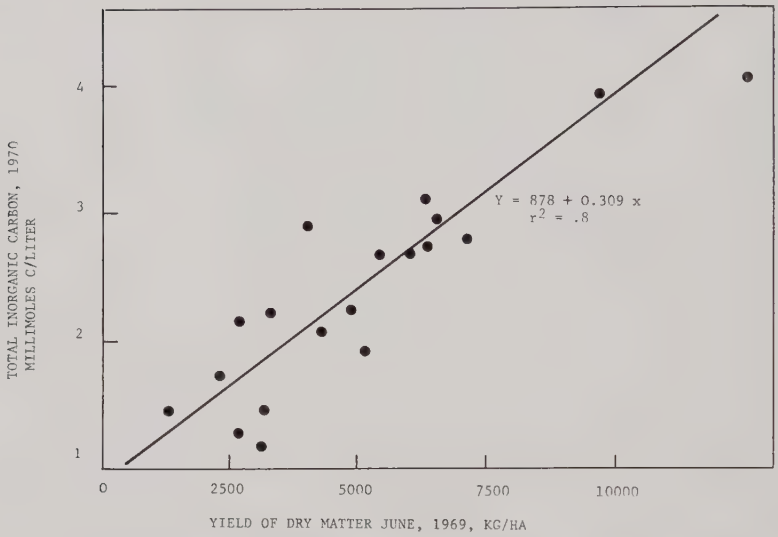

Figure 8. Total inorganic carbon in marsh water (average for June, July and August) plotted against total dry matter yields of vegetation in June of 1969.

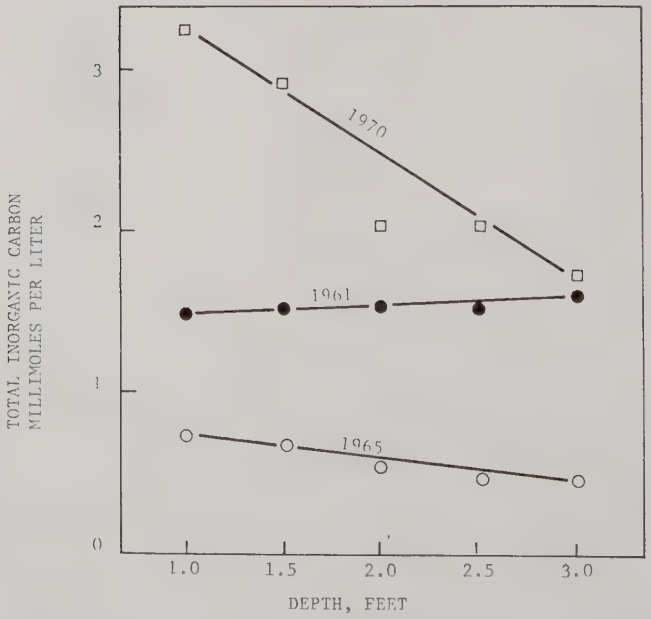

Figure 9. Inorganic carbon content plotted against depth of marshes for three years. Points are experimental observations, lines are drawn in visually for reference purposes.

matter production of the several major species have been made. These observations are summarized elsewhere (Lathwell et al., 1973).

Shown in Table 6 are correlations among C_T (total inorganic carbon in the water), total dry matter production of macrophytes and total dry matter production of emergent species over the period 1966 to 1970. Evidently these variables are all well correlated with each other, indicating that an individual marsh behaves in a similar manner from year to year. Also noteworthy is the high degree of correlation between total dry matter production and total inorganic carbon in solution. Since the bulk of the dry matter production is composed of the emergent vegetation, these correlations lend support to the hypothesis. Inorganic carbon content and dry matter production of emergents are closely related to each other. Hence, if conditions are favorable for growth of emergents, the inorganic carbon content of the water will likely be high. Figure 8 illustrates a typical relationship.

Shown in Figure 9 are the relationships between total inorganic carbon in solution and depth of the marshes for the years 1961, 1965 and 1970. Prior to about 1965, all of the marshes were dominated by submerged species at all depths. However, since 1965, the emergent species have become dominant in the shallowest marshes while in the deeper marshes the emergent species have not been so productive. In effect then the deeper marshes have not changed very much while the shallower ones have changed markedly because of the increased amount of organic carbon added each year when the emergent species fell into the water and because, subsequently, decomposition of this organic matter added inorganic carbon to the water faster than it was lost to the atmosphere or used in photosynthesis. The "excess" inorganic carbon lowered the pH of the water, which led to a gradual dissolution of calcium carbonate and consequent increase in alkalinity.

Seasonal Changes in Water Chemistry

In the period 1966 to 1970, sampling dates were extended into the winter months. The oxygen content and total inorganic carbon content are shown in Figures 10 and 11 for the different months of the year. Both oxygen contents and inorganic carbon contents varied considerably for any given month among sampling years. This was a consequence of several conditions. High oxygen contents can be generated by algal blooms under fairly clear ice. Low oxygen contents can be generated under deep snow over ice, which precludes any photosynthesis while respiration continues at a slow pace. On several occasions, the water in some marshes has been anaerobic, particularly in the winter of 1970.

The changes in inorganic carbon are the inverse of those for oxygen. Illustrated in Figure 12 is a plot of alkalinity against carbon dioxide in

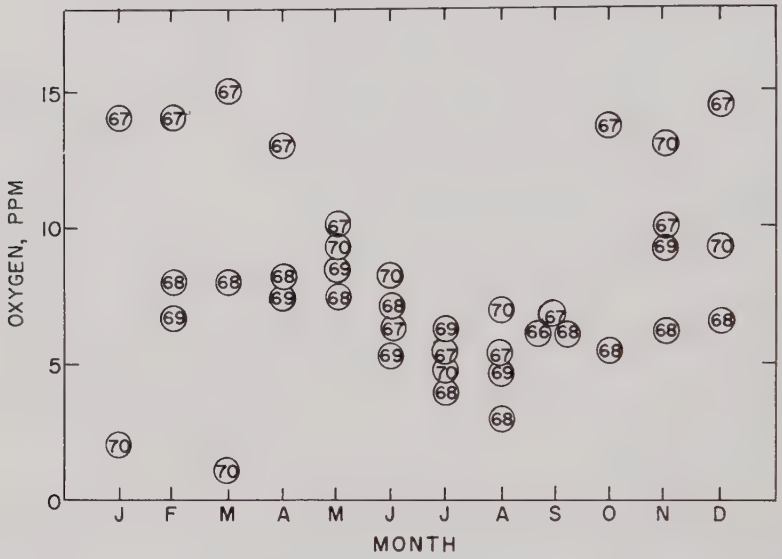

Figure 10. Average oxygen content of water plotted against month for the period 1966 to 1970. Numbers in circles designate year of observation.

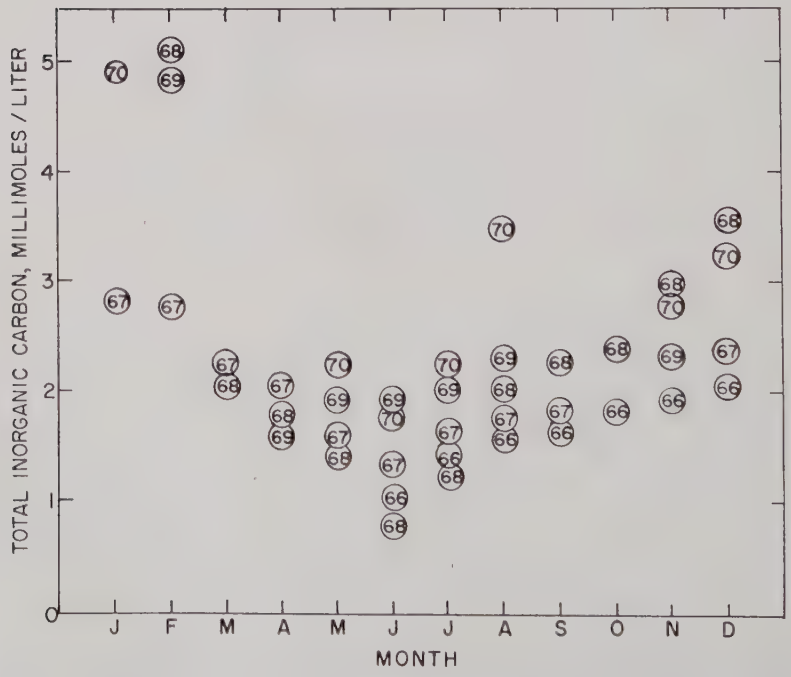

Figure 11. Average values of total inorganic carbon plotted against month of the year for the period 1966 to 1970.

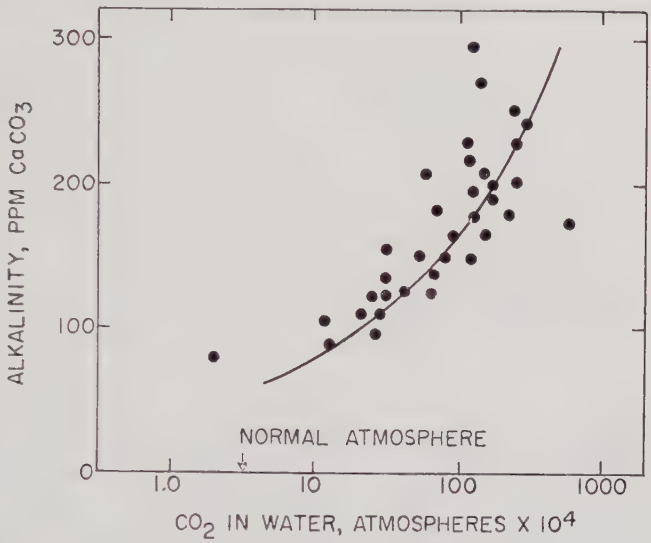

Figure 12. Alkalinity in water plotted against partial pressure of carbon dioxide in the water for January 28 and Novemeber 24 in 1970. Points are experimental observations, the line represents the calcite-carbon system.

water similar to that of Figure 5 except that the data plotted here are for January and November of 1970. Diurnal biological activity was not particularly high preceding these sampling periods so that the water tended toward equilibrium with calcium carbonate as hypothesized earlier, and alkalinity during the winter months tended to be higher than during the summer months.

As pointed out earlier, inorganic carbon tended to be negatively correlated with days from June 1 for the months of June, July and August in the period 1961 to 1965. However, the trends in Figure 11 suggest an increase in inorganic carbon during the same months. Again this reversal of seasonal trends was probably a consequence of accumulation of organic carbon in the water over the early years of the marshes until finally enough organic carbon had accumulated that its rate of decay during the summer months exceeded the photosynthesis rate of the submerged aquatics.

DISCUSSION

The changes in inorganic carbon content of the water appear to be the key variable in interpretation of the temporal changes in water chemistry of the newly established marshes studied here. In turn, the changes in inorganic carbon content are correlated with changes in types of vegetation (emergent vs submergent). Finally, water depth has a major influence on emergent vs submergent vegetation, with the

emergent vegetation being much more important in the shallower marshes. The effect of the emergent vegetation appears to be primarily that of accumulating large amounts of organic matter during the growing season which falls into the water during the winter and, upon decomposition, insures that the inorganic carbon in the water will be high.

Most natural marshes will vary considerably in depth from point to point. The implication of these studies is that water chemistry will be primarily dependent upon the ratio of surface area with depths of 2 feet or less to surface area with depths of 2 feet or more (providing a reasonable amount of emergents occur in the shallows). If a large fraction of the surface is shallow, emergent production would be expected to produce a large amount of organic matter and lateral mixing would supply some inorganic carbon to the deeper water. Hence, marshes with predominately shallow water should contain large amounts of inorganic carbon. On the other hand, predominately deep marshes should have relatively little emergent vegetation and accumulation of inorganic carbon in the water should be limited (unless furnished by some outside source of organic matter).

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MERCURY IN STRIPED BASS AND BLUEFISH[1]

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ABSTRACT

Bluefish and striped bass taken in the vicinity of Montauk Point on Long Island were analyzed for mercury content. In both species, there was a correlation between mercury and weight. Bluefish weighing less than 2.4 kilograms had concentrations of mercury below 0.5 milligrams per kilogram, while in those between 2.4 and 5.6 kilograms the concentration fluctuated above and below that level. All fish weighing more than 5.6 kilograms contained mercury in excess of 0.5 milligrams per kilogram. The corresponding weight categories for striped bass were: less than 3.2 kilograms; between 3.2 and 5.7 kilograms; and more than 5.7 kilograms, respectively.

There is an urgent need for the systematic collection of data on the distribution of mercury in the aquatic environment. Considerable attention is currently being directed toward an assessment of the concentration of mercury in aquatic organisms. Unfortunately, few data have been presented in the scientific literature similar to those of Johnels et al. (1967a, 1967b) and Bache et al. (1971). Until such data do become available (which relate mercury found in the organisms, or parts thereof, to the age, weight, developmental history, location and/or duration of exposure of the specimen), it will be difficult to clarify the normal versus the abnormal distribution of the element in the organism.

Since the concentration of mercury in Block Island Sound ranges from 0.05 to 0.41 ppb (Alexander, unpublished data) and since preliminary analyses of fish taken from this area had, at times, shown elevated concentrations of mercury in the flesh, a more extensive study was undertaken. The New York Ocean Science Laboratory, in conjunction with the State Department of Environmental Conservation, conducted a joint investigation of the mercury content of striped bass *(Morone saxatilis)* and bluefish *(Pomatomus saltatrix)* taken from the waters off Long Island. The immediate aim of the study was to determine the realtionship between the weight of the fish, hence by inference the age, and the mercury content of the edible flesh.

[1] Contribution No. 10 of the New York Ocean Science Laboratory, and Contribution No. 73-3 of the Division of Marine and Coastal Resources.

METHODS

The fish used in these studies were primarily collected from the waters off Montauk Point (6 miles due south, 20 bluefish) and in the surf at Montauk (43 striped bass and 30 bluefish). Additional bluefish were collected at Smith Point (1), King's Park (1), Plum Gut (1), Eaton's Neck (2), Gardiner's Island (1) and Fire Island (1). Additional striped bass were taken at Hart Island (1), Lido Beach (1), Huntington Bay (1) and Shinnecock (1).

Two methods of analysis were used. At the New York Ocean Science Laboratory the method used was that described by the Dow Chemical Company[2] with the following modification: a reduction in the amount of glassware involved in the aeration train, the use of silica gel (non-indicating) which was substituted for the anhydrous magnesium perchlorate, and a longer digestion time (18-24 hours). A Beckman atomic absorption spectrophotometer (Model 440) with a 10-centimeter cell was used in these measurements. The accuracy of the method was checked by determining the mercury content of orchard leaves (National Bureau of Standards, SRM 1571). The analyses showed the concentration to range from 0.18 to 0.22 ppm. The non-certified value listed by the National Bureau of Standards was 0.2 ppm. The precision of the Dow method was checked by determining the mercury content of replicate samples for flesh taken from the same fish. These results showed the precision to be 11 per cent.

The State Department of Environmental Conservation employed the method described by the Association of Official Analytical Chemists (1970), the only modification being the use of a 10-centimeter cell rather than the 11.5-centimeter cell called for. A Perkin Elmer atomic absorption spectrophotometer was used in these measurements. The accuracy of this method was also checked by analyzing the orchard leaves. The results showed the mercury concentration to be 0.21 to 0.22 ppm.

The analytical agreement between these two methods was further checked by measuring the mercury content of the flesh of the same striped bass. Both methods showed this to be 0.28 ppm.

Methyl mercury was determined by the method of Newsome (1971).

RESULTS AND DISCUSSION

Figures 1 and 2 depict the relation between the mercury in striped bass and bluefish and the weight of the fish. In both species there was an increase in the total mercury content with increased weight of the

[2]Available from The Chlorine Institute, Inc., 342 Madison Avenue, New York, N.Y. 10017 as MIR 104 — Analytical Methods for Determination of Total Mercury, at $1.00.

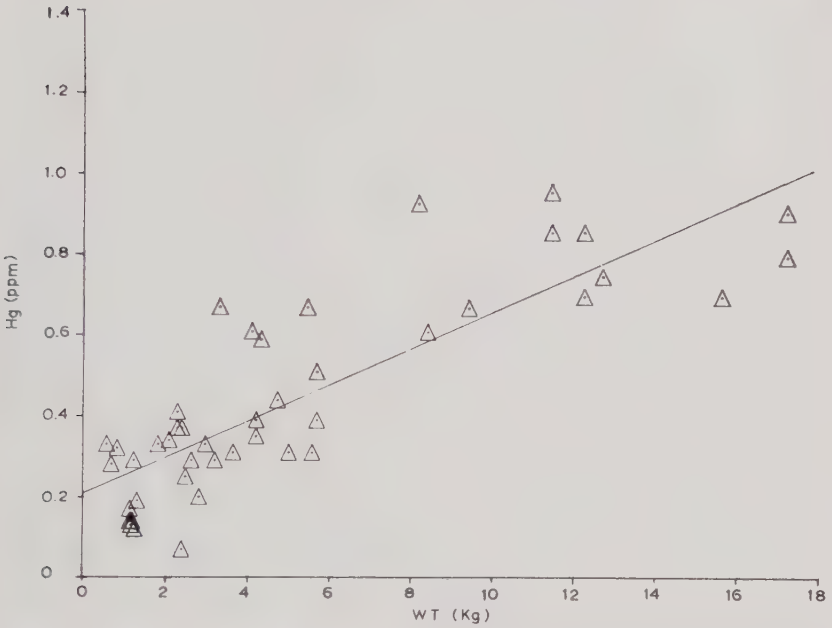

Figure 1. Relation between the mercury content of the edible flesh and total weight of striped bass.

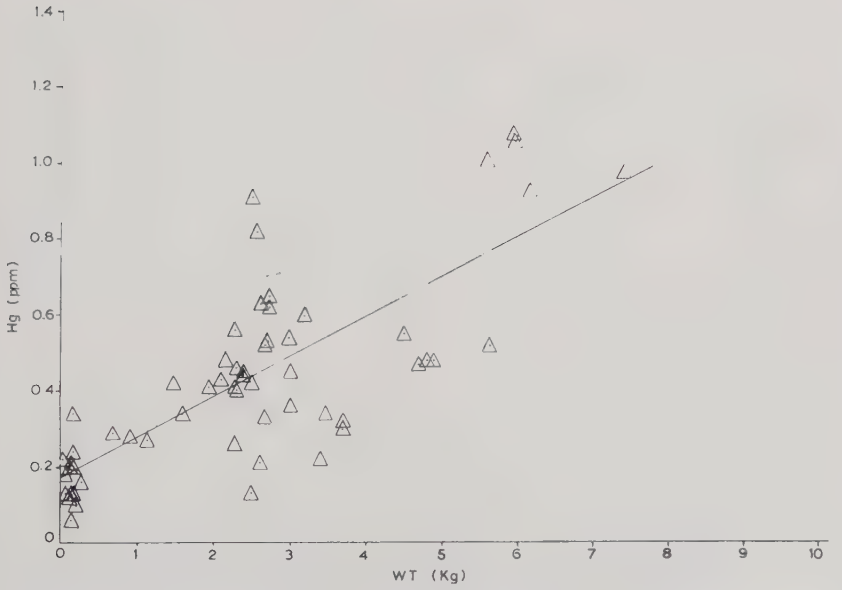

Figure 2. Relation between the mercury content of the edible flesh and total weight of bluefish.

fish. The correlations between total mercury and weight of the fish were 0.84 and 0.77 for the striped bass and bluefish, respectively. The observed scatter (standard error of estimate) in the data was 0.14 for the striped bass and 0.16 for the bluefish.

The line of best fit shows that the bluefish weighing more than 3.2 kilograms and striped bass weighing more than 6.4 kilograms will, on the average, have mercury concentrations greater than 0.5 milligrams per kilogram. The scatter about the line does, however, make these weights somewhat tenuous, more so for bluefish than for striped bass. No bluefish below 2.4 kilograms and no striped bass below 3.2 kilograms had concentrations greater than 0.5 milligrams per kilogram. On the other hand, 14 bluefish weighing more than 2.2 kilograms had concentrations less than 0.5 milligrams per kilogram. The same was true for seven striped bass weighing more than 3.2 kilograms.

An indication that the source of the fish may be an important factor is shown in the bluefish data. Those fish taken from the area southeast of Montauk Point in June and July showed slightly higher concentrations of mercury, as shown in Figure 3, than did those collected from the surf at Montauk in the early fall. This may have been the result of a seasonal change in feeding habits.

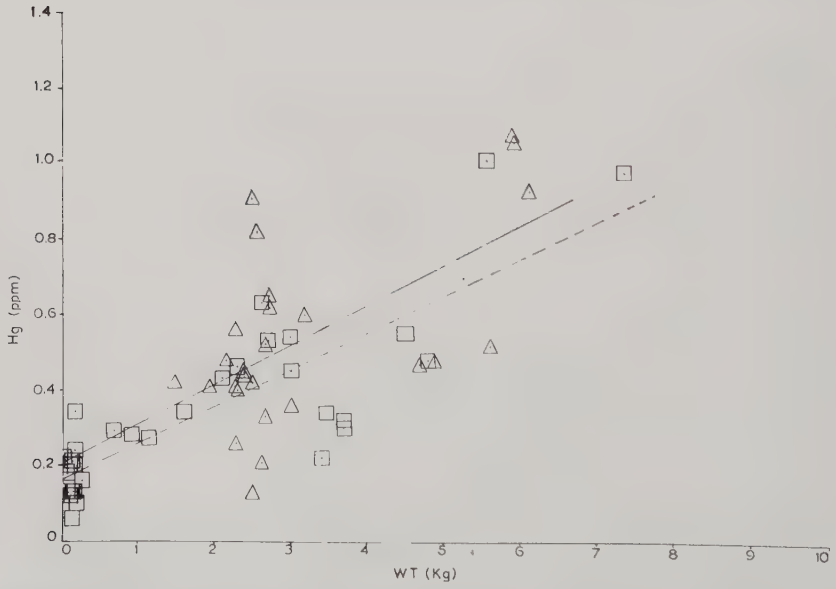

Figure 3. Relation between the mercury content of the edible flesh and total weight of bluefish in different localities. Triangles and squares represent the relation found for those fish taken from the area southeast of Montauk Point and the surf, respectively. The solid and the broken curves are the regression lines for the same localities, respectively.

Correlation values for the total mercury and weight in the offshore- and surf-caught bluefish were 0.60 and 0.84, respectively. The scatter in the data was also much larger for the offshore fish (0.20) than for those taken from the surf (0.12). The precise reason for the difference in the correlation and scatter is not apparent at this time. The mixing of two or more populations of bluefish in the offshore waters, each with its own mercury profile, may have been a factor.

Westoo (1967) and Westoo and Noren (1967) indicated that the mercury in the fish they examined was present primarily as methyl mercury. Ui (1971) showed that the ratio of methyl mercury to total mercury in fish can be quite variable. Bache et al. (1971), working with lake trout of known history in Cayuga Lake (New York), showed that the ratio of methyl mercury to total mercury is strongly influenced by the age of the fish.

In striped bass (only three samples were available) approximately 70 per cent of the total mercury was present as methyl mercury. The weights of these fish were 4.3, 5.7 and 11.5 kilograms. In bluefish, the methyl mercury content ranged from 54 to 87 per cent. Three of the four bluefish, weighing 3.0, 4.8 and 5.9 kilograms, showed 54, 56 and 56 per cent methyl mercury, respectively.

Further studies on the characteristics of the methyl mercury to total mercury ratio in marine fish are in progress.

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MANAGEMENT OF MUSKELLUNGE IN CHAUTAUQUA LAKE

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ABSTRACT

During the 1930's, the muskellunge fishery in Chautauqua Lake began to show a drastic decline due to many accountable factors. A decision was made to protect the remaining population with more restrictive regulations which commenced in 1941. Within a few years the spring netting catch of spawning muskellunge and the angler harvest began to increase. In addition to the more restrictive regulations, a second major management practice initiated in 1941 was maintenance stocking with fingerling muskellunge along with muskellunge fry. Studies conducted between 1961 and 1971 to evaluate the fingerling stocking program have illustrated the importance of the hatchery-stocked muskellunge to the lake fishery. The 1971 data indicate that over half of the muskellunge in the lake originate at the Prendergast Hatchery. Thus, both restrictive regulations and maintenance stocking with fingerlings are vital to this fishery.

Chautauqua Lake is located in the center of New York State's most westerly county, Chautauqua, within the upper reaches of the Allegheny River system. The lake is slightly longer than 15 miles with an average width of 1.5 to 2.0 miles. The total surface area is approximately 13,000 acres at normal summer levels. Chautauqua Lake is two lakes in one. At its mid-point, the lake is only 0.2 of a mile wide, thus creating two well defined habitats.

The upper portion of the lake is relatively deep, has a rubble and gravel bottom, and maintains clear water throughout the summer. The average depth is 30 feet and the maximum 77 feet. The lower half is much shallower, has a muck and sand bottom, and supports extensive rooted acquatic vegetation. The average depth is 15 feet and the maximum 19 feet.

The muskellunge *(Esox masquinongy)* in unquestionably the single most important species of fish in Chautauqua Lake. A special post card census of anglers in 1965 showed that the economic value of the muskellunge fishery was 1.8 million dollars annually.

Prior to 1941, the only regulations on the muskellunge fishery were an open season (July 1 to November 1) and a 24-inch size limit. Between 1910 and 1940, the average number of muskellunge taken in the hatchery pound nets each spring decreased from 3,101 to 583. By the early 1940's it became apparent that the fishery was in dire need of protection.

The reasons for this drastic decline in the muskellunge population were well stated by Cecil Heacox (1946). The increase in fishing pressure, resulting from the availability of the automobile and power

boats, multiplied the annual catch. Fishing tackle became more efficient, with copper lines for deep-water angling plus an increased variety of lures. The 24-inch legal size limit failed to protect the female muskellunge for at least one year of maturity, reducing their opportunity to spawn naturally or to be stripped artificially, prior to angler harvest.

In 1941, many regulations were initiated to protect the remaining muskellunge in Chautauqua Lake. The legal size limit was raised to 32 inches to insure one or more years of potential spawning by the females before becoming susceptible to angling. A creel limit of one per day and five per season was established. The open season was reduced to July 1 through October 15. This protected the muskellunge during the last two weeks of October, when many fish were traditionally harvested by live-bait anglers. The use of metal lines was prohibited, but a 6-foot metal leader was allowed. The use of gaff hooks was also prohibited. In 1947, the legal size limit was lowered to 30 inches.

One of the new regulations, which did not have a direct effect on the muskellunge population but insured a monitoring of the annual harvest, was the special muskellunge license. This license must be returned to the Department of Environmental Conservation at the conclusion of the muskellunge season with catch data, including sizes of fish taken and hours spent angling. This information is the source of annual statistics on the number of fish caught, their average length and weight, and the hours required to land a legal muskellunge. The data obtained from the special license are summarized in Table 1 for the period 1961 to 1971.

Over the 30 years from 1942 to 1971, the special license sales varied between 4,300 and 20,000 annually. After 1961 they averaged 15,000 with very little variance. These anglers usually represented some 25 to 27 states, with some representation from Canada and other foreign countries. New York State residents comprised 70 per cent of the total anglers, but averaged only 60 to 65 per cent of the successful anglers. Ohio and Pennsylvania residents each contributed between 12 and 14 per cent of the total number of anglers, but together they comprised neraly 40 per cent of the total number of successful anglers. No other single state represented more than 1 per cent of the total anglers.

From 1962 to 1971, the average time required to harvest a legal muskellunge varied between 57.2 and 108.9 hours for successful and unsuccessful anglers combined. From 1967 to 1971, this average held at approximately 70 hours. Considering only successful anglers, the average time required to harvest a legal muskellunge averaged about 38 hours from 1960 to 1971.

From 1962 to 1971, the percentage of total licensed anglers successful in landing one or more legal muskellunge varied between 17.7 and

TABLE 1. SUMMARY OF DATA FOR MUSKELLUNGE HARVESTED FROM CHAUTAUQUA LAKE, AS TABULATED FROM SPECIAL LICENSES, FOR THE YEARS 1961 TO 1971

Item	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971
Number of licenses issued	15,256	15,856	16,188	15,394	14,622	15,546	15,483	16,940	16,950	17,735	15,320
Muskellunge caught	5,572	7,720	5,465	5,214	4,004	4,512	6,204	6,937	7,647	6,393	5,304
Average length (inches)	34.1	34.2	34.5	34.1	33.4	33.0	33.0	33.0	33.6	33.8	34.1
Average weight (pounds)	10.8	11.0	11.2	10.6	10.0	9.5	9.5	9.4	9.6	9.8	10.3
Hours to harvest a legal muskellunge											
All anglers	102.4	102.2	102.2	102.2	108.9	102.2	74.9	78.4	57.2	68.2	82.4
Successful anglers	42.1	38.1	46.5	42.6	42.4	39.1	35.9	43.5	27.9	28.4	32.7
Successful anglers (per cent)	21.8	22.8	21.4	20.5	17.9	17.7	21.7	23.0	24.8	21.5	20.3

24.8 per cent. The average success rate over this period was 21.2 per cent.

The annual harvest of legal-sized muskellunge in Chautauqua Lake from 1962 to 1971 varied between 4,004 and 7,720, averaging slightly less than 6,000. The average length and weight varied slightly from one year to the next, but they were usually close to the over-all averages of 33.8 inches and 10.1 pounds. In a season such as 1971 when there was a noticeable absence of 5- and 6-year-old muskellunge, the average size will increase, reflecting the lack of minimum-sized (legal), younger fish.

As of 1971, the average annual yield of harvested muskellunge was slightly in excess of 30 tons, ranging from 20 to 40 tons. The average annual yield of legal-sized muskellunge per acre was 4.6 pounds. Variance in pounds of legal fish harvested depends not only on the availability of harvestable fish, but also on angling pressure.

In an effort to expand the recreational opportunity at Chautauqua Lake, the open season for muskellunge was extended in 1964 to include the last two weeks in October (16 through 31). The computed catch data indicate that only a small percentage of the total number of muskellunge harvested each year were taken during the extended season. In 1964, only 6.4 per cent of the total catch was made from October 16 to 31, while in succeeding years the percentages were: 4.0 in 1965; 3.5 in 1966; 5.4 in 1967; 7.6 in 1968; 7.6 in 1969; 3.5 in 1970 and 10.3 in 1971.

In 1966, the open season was further extended to begin on the third Saturday of June instead of July 1. Since this early opening date has been in effect, the heavy angling pressure previously experienced in July has been shifted to June. From 1966 to 1971, the percentage of the total catch realized in June varied between 13.4 and 26.7, and the percentage caught in July dropped significantly.

In 1971 and 1972, a special 6-day winter season for muskellunge was in effect. The total muskellunge harvest during these two seasons was four fish in 1971 and 10 in 1972. Angling pressure was very light, a great percentage of the anglers fishing for species other than muskellunge, i.e., yellow perch and walleye.

Probably the single most significant management tool employed at Chautauqua Lake has been maintenance stocking with 6-inch or larger muskellunge fingerlings. The annual recommendation for stocking is 13,000 6-inch fish. The total number and sizes of muskellunge planted depends on hatchery production, and accordingly, the number planted has varied between 1,100 and 17,500 fingerlings from 1961 through 1971. The number fin-clipped and planted since 1961 is summarized in Table 2.

TABLE 2. SUMMARY OF FIN-CLIPPED MUSKELLUNGE PLANTED IN CHAUTAUQUA LAKE FROM 1961 TO 1971

Year	Number	Average length (inches)
1961	10,300	6.1– 7.1
1962	9,200	7.8
1963	17,500	7.7
1964	7,000	7.4
1965	. .	. .
1966	1,100	6.2– 7.2
1967	5,800	5.9– 7.4
1968	15,800	3.5– 6.1
1969	9,000	6.9– 9.2
1970	1,700	8.0–10.1
1971	17,000	4.0– 9.0

Prior to 1965, many muskellunge in the 2- to 4-inch size range were planted in the lake in addition to the larger, marked fingerlings. Also stocked on an annual basis prior to 1965 were two to four million muskellunge fry. These fish were mostly planted as advanced swim-up fry.

The significance of the hatchery-reared, fin-clipped muskellunge to the total population has been studied since 1961. Each year six to 12 pound nets were set in the lake for the primary purpose of collecting muskellunge spawn for the hatchery operation. The number of adult muskellunge captured with these nets each spring ranged between 1,000 and 3,000. A high percentage of these fish were examined by Department biologists. Fin-clips, length and sex were recorded.

Muskellunge from age group IV were usually the youngest fish captured with these nets, but a few individuals from age groups I, II and III were taken. All age groups from IV through X were usually represented in the nets in significant numbers. From 1967 to 1971, the percentage of fin-clipped muskellunge of hatchery origin in the total net catch increased from 38.5 to 50.9 per cent. When only four age groups of marked fish were represented in the nets, 38.5 per cent were of hatchery origin. In 1971 when a total of six age groups of marked muskellunge were represented, over 50 per cent of the catch were of hatchery origin. During the years 1968 to 1970 when five age groups of marked fish were significantly represented in the netting catch, slightly over 45 per cent of the fish were of hatchery origin. During years when cursory checks of anglers were conducted, the percentage of fin-clipped fish of hatchery origin in the legal harvest seemed to follow closely the netting percentage for the same age group.

In order to investigate the extent of any successful natural spawning in Chautauqua Lake, some fall electrofishing was conducted from 1968

to 1971. Over this 4-year period, 88.5 per cent of the total young-of-the-year muskellunge captured were hatchery-reared fish. The electrofishing was conducted in many areas throughout the lake, both near pound net sites and many miles from any net site. The percentage of hatchery-reared to naturally-spawned muskellunge did not change significantly at any given location.

There have been two major tagging studies at Chautauqua Lake over the past 30 years. Between 1941 and 1946, a total of 7,601 adult muskellunge were tagged with a metal strap tag attached to the anterior base of the dorsal fin. These tags were returned on a voluntary basis by anglers harvesting legal-sized fish. Over a 20-year period (1941 to 1960) 753 tags were returned to the Department. This represented an actual return from the angler of nearly 10 per cent of the fish tagged.

Between 1961 and 1965, a total of 5,886 adult muskellunge were tagged with a metal strap tag. Voluntary returns between 1961 and 1971 totaled 1,067, or 18.1 per cent of the number tagged. This increase in actual returns may have been due in part to an intensive publicity campaign which informed the anglers of the location of the tag on the fish and the importance of its return. Another reason for better returns may have been the wording on the tag informing the angler where to send it.

In 1967, a male muskellunge captured in a pound net bore a dorsal fin strap tag that had been attached to the fish in 1941. During the past 10 years other muskellunge with tags attached during the 1940's have been captured. Records such as these reveal that some muskellunge in the lake live to 30 years or more.

In conclusion, it should be noted that many factors have contributed to the improved muskellunge fishery in Chautauqua Lake. Regulations such as daily and seasonal creel limits, a minimum legal size limit and gear restrictions protect the population for a minimum of one year after becoming sexually mature. In this way, an adequate brood stock has been assured along with a better distribution of the total catch. Maintenance stocking with fingerlings has demonstrated its value to the total population. Although some natural spawning does produce legal-sized fish, the hatchery-reared muskellunge play a significant role in the total composition of the fishery. The fact that Chautauqua Lake has maintained a relatively stable muskellunge fishery for 25 years, as reflected by the harvest figures, is some indication that the management practices, which are still in effect, are sound.

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INCIDENCE OF LIVER FLUKES IN A SAMPLE OF WHITE-TAILED DEER FROM THE ADIRONDACKS[1]

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ABSTRACT

A sample (147) of white-tailed deer, taken in the Adirondacks by hunting from 1966 to 1970, was examined for adult liver flukes (*Fascioloides magna*). No flukes were found in fawns, and significantly ($p \leq 0.05$) fewer yearlings (12.5 per cent) were infected than adults (62.0 per cent). Parasites were found in adults in all five years, but in yearlings only in 1967. Maximum incidence among adults was 77.8 per cent in 1968, significantly greater than the 51.7 per cent recorded in 1966. The incidence of 51.7 per cent for yearlings and adults combined was significantly greater than that reported in previous studies.

Cheatum (1951, 1952) clearly established that the occurrence of liver flukes *(Fascioloides magna)* in white-tailed deer *(Odocoileus virginianus)* in New York as essentially restricted to the Adirondack region. In 256 Adirondack specimens, he found an incidence of 25.4 per cent over all seasons, with the greatest incidence (59.3 per cent) among adults and yearlings combined in spring. The lowest incidence in adults and yearlings was 20.0 per cent, found in a small sample of 15 fall-killed deer. This paper compares the results of the examination of 147 fall-killed animals taken from 1966 to 1970 with Cheatum's findings and reports the data by sex for three age groups.

METHODS AND MATERIALS

All of the deer examined in this study were taken by hunters on an 8.15-square-mile area in the central Adirondacks. The study area is a portion of The Archer and Anna Huntington Wildlife Forest near Newcomb in Essex County. Pre-hunting season (early October) deer densities were estimated by deer drives to have been 27 per square mile in 1966, 17 in 1967, 13 in 1968 and 12 in 1969 and 1970. Details

[1] A contribution of the Archer and Anna Huntington Wildlife Forest program of the Adirondack Ecological Center of the State University of New York College of Environmental Science and Forestry. The support of McIntire Stennis Project J and the Fish and Wildlife Management Act program of the New York State Department of Environmental Conservation is gratefully acknowledged.

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of the methods of population estimation, hunting, etc. were given in Behrend et al. (1970).

Livers from 147 deer were examined for adult liver flukes by slicing diagonally across the anterior and superior surfaces. Incisions were made approximately one-half inch apart until one or more parasites were found or until the entire liver had been so incised. The larger portions of the hepatic ducts were probed if the incisions alone revealed no flukes. Particular attention was devoted to any discoloration or lesion encountered on the surfaces of the liver or during disection. Deer were aged by the tooth replacement and wear criteria described by Severinghaus (1949). Statistical comparisons were restricted to 2 x 2 chi-square tests, employing an *appriori* significance level of 0.95.

RESULTS AND DISCUSSION

Results of the examinations are given in Table 1. The 51.7 per cent incidence among yearlings and adults combined was significantly ($\chi^2 = 5.35$, $p \leq 0.02$) greater than the 20.0 per cent reported by Cheatum (1952). The absence of adult liver flukes in 31 fawns confirms Cheatum's findings for two specimens. Further comparisons are impossible due to lack of more detailed age, sex and time information in Cheatum's reports.

The present data, for all years, showed no adult flukes in fawns, a 12.5 per cent incidence among yearlings (1½ year olds) and a 62 per cent incidence among older deer. The difference between yearlings and older deer was statistically significant ($\chi^2 = 18.65$, $p \leq 0.01$). Parasites were found in adults in all five years, but in yearlings only in 1967. Differences among adults for individual years or by sex were not significant.

Post mortem examinations of fall-killed deer from a large private estate in the central Adirondacks suggest incidences of 60 per cent or higher (personal communication, R.A. Lopez D.V.M.). In contrast, no flukes were found in 746 fall-killed deer examined at the Seneca Army Depot near Waterloo in central New York. In addition, of 84 deer from all parts of the State, examined for flukes in 1970 and 1971, only three were positive. Two of these were from the Huntington Forest and one was from nearby in Essex County (personal communication, Dr. Ward B. Stone from data gathered under Federal Aid Project W-35-R).

These findings indicate that liver flukes can be easily detected in from 50 to 78 per cent of the adult deer in the central Adirondacks during the fall. True incidence among adults may be higher, but was undetected in our work due to the gross nature of the examinations. The importance of these parasites to the condition and survival of white-tailed

TABLE 1. INCIDENCE OF ADULT LIVER FLUKES (*Fascioloides magna*) IN WHITE-TAILED DEER TAKEN BY HUNTING FROM 1966 TO 1970 ON THE HUNTINGTON WILDLIFE FOREST

Year	Female		Male		Total	
	Number	Per cent	Number	Per cent	Number	Per cent
Fawn						
1966	5	0.0	8	0.0	13	0.0
1967	5	0.0	4	0.0	9	0.0
1968	6	0.0	2	0.0	8	0.0
1969	1	0.0	..	..	1	0.0
1970	..	..	..	..	..	0.0
Total	17	0.0	14	0.0	31	0.0
Yearling						
1966	1	0.0	3	0.0	4	0.0
1967	5	40.0	9	11.1	14	21.4
1968	1	0.0	2	0.0	3	0.0
1969	2	0.0	..	..	2	0.0
1970	..	..	1	0.0	1	0.0
Total*	9	22.2	15	6.7	24	12.5
Adult						
1966	22	50.0	7	57.1	29	51.7
1967	18	77.8	10	50.0	28	67.9
1968	15	80.0	3	66.7	18	77.8
1969	13	53.8	..	..	13	53.8
1970	1	0.0	3	66.7	4	50.0
Total*	69	63.8	23	56.5	92	62.0

* Incidence for yearlings and adults combined (116 specimens) was 51.7 per cent.

deer is unknown, but Cheatum found a significantly greater incidence of liver flukes in winter-killed deer than in deer that died from other causes. He suggested that flukes and other parasites have debilitating effects on deer, apparently reducing their chances of survival in severe winters. If he was correct, the higher incidence of liver flukes found in the present study suggests that this parasite may influence some Adirondack deer populations more severely than previously suspected.

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LIVE TRAPPING FOR DOMESTIC DOG CONTROL

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ABSTRACT

Cage-type dog traps and modified European hare traps were used in attempting to live trap domestic dogs. A total of 198 trap nights and 166 trap days at nine locations produced a catch of three dogs. Traps actually visited by dogs averaged 29 trap nights and 17 trap days per dog caught. Three different baits were used, but no specific bait is recommended since baits were not systematically deployed.

Free-running domestic dogs are a constant source of harassment to deer. In New York, it has been legal for many years for conservation officers to shoot dogs chasing deer (§ 186, Fish and Game Law). However, this has rarely been an effective method of dog control, and it frequently creates adverse public opinion. Steel trapping is highly effective on other species of canids, particularly foxes, but for obvious reasons would not be publically acceptable for use on domestic dogs. As part of a special study to learn more about the factors which limit deer populations, a limited effort was made to live trap dogs in the Town of Malone in Franklin County during a special dog quarantine in the spring of 1972.

METHODS

Two basic forms of cage-type live traps were employed: dog traps (National Live Trap Co.) and modified European hare traps. Two of the dog traps measured 69 x 30 x 30 inches and one 48 x 22 x 27 inches. These traps had a treadle which served as a spring door rising from the bottom of the trap after an animal had entered and tripped the baited trigger mechanism at the opposite end. To facilitate use for large dogs, this treadle was removed and replaced by a simple pull-string attached at the closed end to the bait and at the other end to a pin which, when pulled, released a sliding door. On entering, an animal would move the bait which jerked the string and released the sliding door behind it. The modified European hare traps (60 x 28 x 24 inches) operated on the same principle. The original hare traps had sliding doors at each end and a trigger in the middle. This arrangement was not large enough to allow normal-sized dogs to enter and be trapped. Therefore, one end was blocked shut, and the trigger mechanism was moved to that end to allow most breeds to be caught.

Three dog traps and four hare traps were used. On March 7, three traps were positioned 30 feet, 50 feet and 150 feet, respectively, from

the Hicks Road and one at the Constable village dump; these were set each night through April 5. On March 8, three additional traps were set on Barre Hill, at least one-half mile from any road open to traffic. Of the latter, one was active at that location until April 5. The other two were active there through March 14 but were inactive on the night of March 15 and were relocated 150 feet off the Brown Road on March 16 where they were active through April 5. All traps were placed in areas where dog activity was expected (Hicks Road) or observed (Constable dump, Barre Hill and Brown Road). No particular trap pattern was followed.

All traps were checked twice daily except for five occasions when they were checked only once. The first check was made in the forenoon between 9:00 a.m. and 12:00 noon, and the second was made between 12:00 noon and 4:00 p.m. A trap night was the period from the afternoon setting until the trap was checked the following morning. A trap day was the period that a trap was set between the morning and afternoon checks.

Three baits were used: honey bait, the Davies bait and fresh venison. The first two are specially prepared and have been used by the Department's rabies-control trappers to trap foxes. Both have the same base: a mixture of ground glands, including musk glands from muskrat *(Ondatra zebethica)*, castor glands from beaver *(Castor canadensis)*, perineal glands from Abyssinian civit *(Civettictis civetta)*, tarsal glands from white-tailed deer *(Odocoileus virginianus)* and musk glands from the belly of musk deer *(Mosehus moschiferus)*, combined with honey. The Davies bait is different in that various seasonal attractants, such as oats or venison, are added. A lure of coyote anal glands and urine and skunk essence was spread in the vicinity of the trap to attract wandering dogs.

RESULTS

A total of 198 trap nights and 166 trap days resulted in trapping 10 animals including three dogs. Total trap nights per dog caught were 198, and total trap nights per dog caught at traps visited by dogs were 29. Total trap days per dog caught were 83, and total trap days per dog caught at traps visited by dogs were 17. Two of the three dogs were trapped during the daytime period. The records are summarized in Table 1.

The first dog (a mongrel) was caught between 4:00 p.m. on March 22 and 11:00 a.m. on March 23 at the Constable dump. This dog was an unlicensed male with no rabies tag. Its estimated weight was 25 to 50 pounds, and its toenails were well worn indicating that it had been running at large for some time. The second (part St. Bernard) was

TABLE 1. SUMMARY OF LIVE TRAPPING FOR DOGS IN THE TOWN OF MALONE, 1972

Location	Trap type	Trap nights	Trap days	Catch made		Nature of catch	Trap nights per catch	Trap days per catch
				Night	Day			
Hicks Road	Dog (large)	29	24	2	0	fisher raccoon	14	..
Hicks Road	Dog (small)	29	24	0	0	..	..	..
Hicks Road	Dog (large)	29	24	2	0	fisher raccoon	14	..
Constable dump	Hare	29	24	4	0	cat skunk dog raccoon	7	..
Barre Hill	Hare	28	24	0	0	..	..	..
Barre Hill*	Hare	6	6	0	0	..	..	..
Barre Hill*	Hare	6	6	0	0	..	..	..
Brown Road	Hare	21	17	0	1	dog	..	20
Brown Road	Hare	21	17	0	1	dog	..	20
Total		198	166	8	2	xxx	25	83

* These traps were shifted to Brown Road on March 16.

caught between 10:00 a.m. and 3:00 p.m. on March 28 on the Brown Road. This dog was also an unlicensed male with no rabies tag. Its estimated weight was 100 pounds and its toenails were well worn. The last dog (a mongrel) was caught between 10:15 a.m. and 2:45 p.m. on April 3 on the Brown Road. This unlicensed male with no rabies tag was estimated to weigh 25 to 50 pounds and also had well-worn toenails. All three dogs were taken to the dog warden, kept five days and destroyed. Autopsies revealed no venison in the digestive tract.

Catch results by type of bait used are given in Table 2. These results are not comparable since the three baits were not used equally at all trap locations. The honey and venison baits were used indiscriminantly, but only for 18 trap nights and 14 trap days. The three dogs were caught where the Davies bait was used. At traps where dogs visited and where the Davies bait was used, the number of trap nights and trap days per dog caught were 28 and 18, respectively. Based on this brief experience, 25 to 30 trap nights or 15 to 20 trap days would be needed to live trap one dog in areas where dogs are active.

CONCLUSIONS

This pilot trapping program was not intended to lead to specific recommendations for live trapping dogs. The objective was merely to learn whether or not dogs could be live trapped. The results show that the live trapping of dogs in remote locations is possible.

TABLE 2. CATCH RESULTS ACCORDING TO TYPE OF BAIT

Type of bait	Trap nights	Trap days	Catch	Trap nights per catch	Trap days per catch
Honey	4	0	1 (fisher)	4	..
Venison	14	14	1 (fisher)	14	..
Davies	180	152	8 (dog—3) (raccoon—3) (skunk—1) (cat—1)	30	90
Total	198	166	10	25	83

The next question is how effective and practical would live trapping be on a large scale in deer wintering areas. The authors feel that the use of cage-type live traps by themselves would not be completely effective in a dog-control program. Live traps that are large enough to hold all sizes of dogs are bulky to move and expensive to buy or time consuming to build. Word that dogs are running deer comes on short notice. Frequently, in the Adirondacks, remote areas are involved. These situations require a flexible trapping program which the live trap alone cannot provide. The use of an effective, humane snare in conjunction with a limited number of live traps may be a solution to this problem.

GENERAL NOTES

A LARGE SNAPPER (Lutjanidae) FROM LONG ISLAND WATERS[1]

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On September 27, 1966, a large snapper (*Lutjanus* sp.) was taken in 10 fathoms of water off Long Island south of Shinnecock Inlet by the commercial trawler "Metacomet". The fish was brought to the attention of the author by the vessel's captain, George Bangston, and made available for viewing at the C & N Fisheries dock at Hampton Bays (N.Y.) two days after capture. Unfortunately, circumstances permitted only cursory inspection of the iced specimen by Department biologists at that time. Before a subsequent, more detailed examination could be conducted, the fish was frozen and forwarded to a taxidermist. Further efforts at retrieving additional anatomical data from the taxidermist proved fruitless.

Morphological observations were recorded as follows: weight, 64.5 pounds (29.0 kilograms); total length, 1,150 millimeters; standard length, 940 millimeters; head length, 350 millimeters; body depth, 350 millimeters; eye diameter, 40 millimeters; dorsal fin, rays X-14; anal fin, rounded, rays III-9; pectoral fins, falcate, rays 17; caudal fin, slightly lunate with lobes not much produced, rays 15; vomerine tooth patch ⌒ -shaped with a short median backward extension; canine teeth, two very strong in upper jaw, seven moderate in lower jaw; gill rakers, eight developed on lower limb of first arch. The body color was generally pale rose-red with bluish-gray overtones dorsally, shading to pinkish-gray ventrally. All fins were pale rose or pink, becoming dusky toward the tips.

With few discrepancies, the data seem to conform best to the descriptions of either the cubera snapper (*Lutjanus cyanopterus*) or the dog snapper (*Lutjanus jocu*) as given by Jordan and Evermann (1898), Rivas (1949), Anderson (1967) and Bohlke and Chaplin (1968). The specimen's size and weight alone would appear to eliminate other species. Although all previous United States occurrences of *L. cyanopterus* have been recorded from waters south of Cape Hatteras (Rivas, 1949; Moe, 1966; Schwartz, 1972), the observed and supplementary data suggest that the specimen was most likely this species.

Both the cubera snapper and the dog snapper have been described as having reddish hues on the body and on some fins, but only *L. jocu* has been recorded as having orange-red or orange-yellow tinges. The current specimen was distinctly rose-red with grayish overtones, similar to the coloration described for *L. cyanopterus* by Rivas (1949). Rivas also reported five to seven, usually six, developed lower limb gill rakers for *L. cyanopterus* but seven to ten, usually eight or nine, for *L. jocu, L. griseus* and *L. apodus*. Anderson (1967), however, recorded seven to eight developed rakers (or 11 to 15 including rudiments) for *L. cyanopterus*. Although anal fin ray counts have been recorded as III-8 for both *L. cyanopterus* and *L. jocu* by several authors (Jordan and Evermann, 1898; Meek and Hildebrand, 1925; Moe, 1966; Anderson, 1967; Schwartz, 1972), Rivas (1949) reported a count of III-8½ for an Atlantic coast record of *L. cyanopterus*. It is entirely possible that the anal fin ray count of the current specimen was III-8½, since the posterior ray, if split, may have been counted erroneously as two distinct rays. Moreover, although the vomerine tooth patch of *L. cyanopterus* has been described as ⌒ -shaped (Jordan and Evermann, 1898) or crescent shaped (Rivas, 1949; Anderson, 1967; Bohlke and Chaplin, 1968; Schwartz, 1972) without a distinct posterior extension on the median line, Jordan and Evermann also reported that the tooth patch of *L. cyanopterus* sometimes occurred "... with a short

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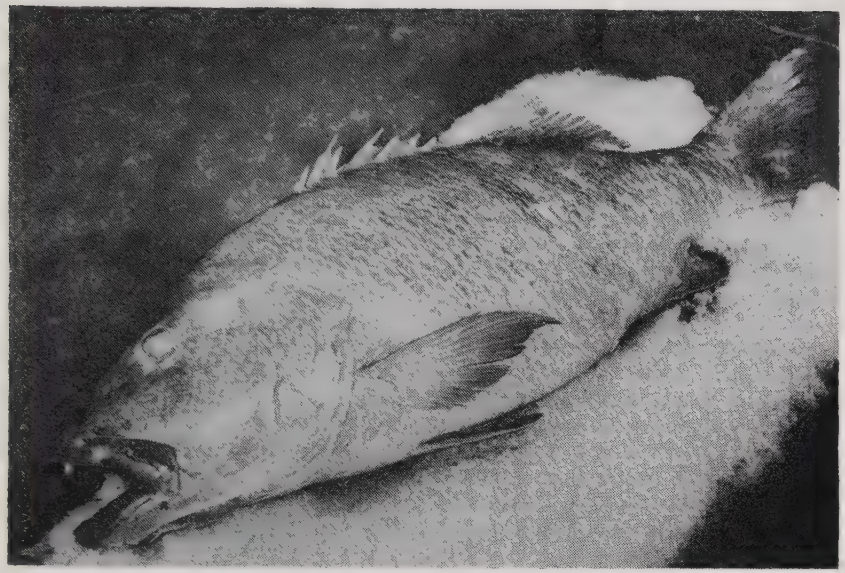
[1] Contribution No. 73-6 from the Division of Marine and Coastal Resources. The author sincerely wishes to thank Dr. Frank J. Schwartz of the Institute of Marine Sciences at the University of North Carolina for his critical review of the manuscript.

[2] Present affiliation: Division of State-Federal Relationships, Office of Resource Management, National Marine Fisheries Service, Washington, D.C. 20235.



Large snapper (Lutjanidae) from New York Waters. (Photo by courtesy of Richard Catena)

median prolongation (⌒ -shaped), its length always less than the width of the patch in front; . . ." The tooth patch extension on the current specimen conformed to this description and was certainly much shorter than that illustrated by Anderson (1967) for *L. jocu, L. apodus* and *L. griseus*. Finally, although not recorded at the time of observation, the cheek scales visible in the accompanying photograph clearly appear to occur in nine or 10 rows. Anderson (1967) reported that the cheek scales on *L. cyanopterus* occur in eight to 10 rows, usually nine, while those on *L. jocu, L. griseus* and *L. apodus* occur in only six to nine rows, usually seven or eight.

If the identification of the specimen as *L. cyanopterus* is correct, then this is a first record for the species in New York waters and represents a northward range extension of approximately 500 miles (806 kilometers).

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OBSERVATIONS OF WILD CANIDS CHASING DEER

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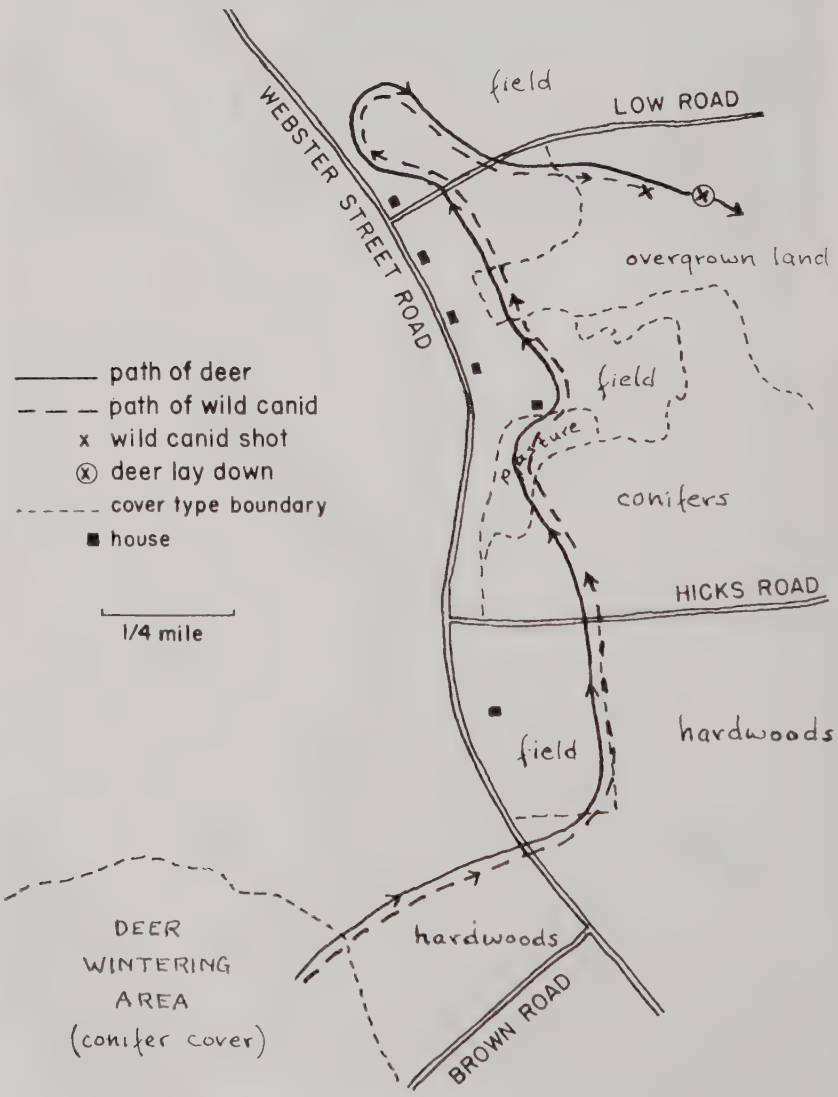
The wild canid (*Canis latrans* var.) as described by Lawrence and Bossert (1969) and later by Silver and Silver (1969) is now common throughout upstate New York. A total of 185 wild canid carcasses were examined at the Wildlife Research Laboratory at Delmar between 1957 and 1971. These specimens came



from 34 counties statewide, and all the eastern counties except Rockland were represented. The popular belief, particularly in the Adirondacks, is that these animals commonly kill deer and have a significant effect on deer populations. Valid testimony from various sources does not uphold this opinion. Letters from hunters and trappers frequently refer to canids ("coydogs", "wolves", "brush wolves") chasing deer, but in very few cases have these persons actually witnessed a kill. Usually it was inferred that a deer was killed by canids when a person happened on a fresh carcass which had been fed on by dogs or possibly wild canids. Such evidence is circumstantial, and death may well have been from some other cause. Wild canids frequently carrionize carcasses of starved or road-killed deer. Venison was commonly found in the stomachs of canids autopsied at the Delmar Laboratory.

The two incidents that follow are eye-witness accounts of wild canids chasing deer. In the first instance the deer was killed and the canid escaped, while in the second the canid was killed and the deer escaped.

On April 25, 1972 Guy Marshall, who lives on Lake Titus in the Town of Malone in Franklin County, saw a dog-like animal chasing a deer through the heavy slush on the lake ice. The animal worried the deer to the point of exhaustion while Mr. Marshall called Special Game Protector Lyndon Raville and then returned to the scene with his gun after being told by Raville to shoot the animal. Marshall fired and missed, and Raville arrived later to claim the deer which had been killed. From Marshall's description, Raville determined that the animal was a wild canid. The animal repeatedly circled the deer and attacked from the right side. Hair and skin were missing from the rib cage on the right side and muscle tissue was torn away. There were puncture wounds on the throat. Dogs generally attack from the rear and tear flesh from the hind quarters (Siegler et al., 1968; unpublished project records). There was massive hemorrhaging in the thoracic cavity, and most of the abdominal viscera had been eaten away including the reproductive tract. The deer was a 6-year-old doe with an estimated round weight of 125 pounds. Fat content of the femur bone was less than 5 per cent, indicating that the deer was in extremely poor condition and in this condition could not have run far before becoming exhausted.

On December 29, 1972 Gus Gravell of Webster Street Road in Malone reported to officer Raville that a dog-like animal was chasing a deer near his property. A long chase ensued before Raville arrived on the scene and dispatched the animal. The deer, an adult buck, lay down under a nearby tree and rested for about 20 minutes before regaining its breath; then it bounded into nearby cover. The dead animal was identified as a female wild canid with a light yellowish coat and weighed about 25 pounds. The carcass was taken to Syracuse University for autopsy. Raville retraced the path of the chase which is shown in the accompanying sketch.

It is noteworthy that the wild canid stayed on the deer's right flank throughout the chase. The chase began in a deer wintering area on the Brown Road and ended about 3 miles away where the canid was shot. Weather conditions during the winter had been mild up to this point, and the deer appeared to be in good condition. Two other wild canids were reported and tracks were seen in this deer wintering area during the winter of 1972-73, but there was no further evidence of deer being killed.

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OBSERVATIONS ON THE MONK PARAKEET IN NEW YORK STATE[1]

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The monk, gray-breasted, gray-headed or quaker parakeet (*Myiopsitta monachus*), a native of Argentina, Bolivia, Brazil, Uruguay and Paraguay, has been observed in a free-flying state in the New York metropolitan area for the past four or five years (Bull, 1971). In 1968 alone, an estimated 12,000 monk parakeets were imported into the United States as cage birds (Banks, 1970). Birds escaping from importers and pet owners are thought to be the source of the present population in New York State (Bump, 1971).

The monk parakeet has been considered an agricultural pest in Argentina since 1947, and the Argentine government is carrying on a program to eradicate it. Crop damage in Argentina has ranged from 2 to 45 per cent in crops such as corn, millet, sorgum and various types of fruit (Bump, 1971). Conceivably, additional problems such as the introduction of exotic diseases and strong interspecific competition with native bird species could result from the presence of the monk parakeet in New York.

The authors captured or shot 55 monk parakeets, collected 12 eggs and inspected six active and two bachelor nests, mainly in the New York metropolitan area, from June 1 to August 11 in 1973. The birds were taken from or near the eight nests of which five were located on Long Island, two on Staten Island and one near Troy. Thirty-four (62 per cent) of the birds were juveniles. Of the adults, nine were females and 12 were males.

No sexual dimorphism was observed. Adults average 11 to 11½ inches in length and weigh 90 to 100 grams. They have a light gray (almost white) forehead, crown, cheek, chin and breast. The throat and foreneck show a slate-gray scalloping. The upper tail coverts, wing coverts and back feathers to the nape are light green. The tail feathers are dark green dorsally with a dark blue rachis. The tail form is similar to the mourning dove (*Zenaidura macroura*).

There are at least two characteristics which distinguish adults from juveniles. The adult has light gray-white feathers on the forehead and crown, while the juvenile has slate-gray feathers on the forehead blending to green on the crown. The difference in pattern is shown in Figure 1. The second characteristic is that premaxillary tubercles are present on the beak of the juvenile but not the adult. Both of these features differentiate adults from juveniles up to at least 3 months of age. The tubercles are normally lost at about 2 months, but pale scars are still visible at 3 months.

The monk parakeet is gregarious. It also is communal in nesting. Its nest structures not only provide places for egg laying and rearing young but also serve as roosts throughout the year. Of interest is the fact that all six active nests observed harbored nesting house sparrows (*Passer domesticus*) in their periphery.

The nest structure is a bulky, somewhat cylindrical affair usually 3 to 4 feet long and something over half as deep. It is built of interwoven twigs 1 to 2 feet long and seldom more than ¼ inch in diameter which gives it a bushy appearance. Most of the twigs used are taken as live wood from trees and shrubs, but the birds are usually unable to cut them cleanly. Rather, they rotate the beak back and forth until the twig is finally severed leaving a ragged cut. The nests inspected were built 20 to 40 feet from the ground on transformer boxes, telephone poles, trees, a roof overhang, a silo and the honeycombed aluminum grating over an aircraft plant entrance. Nests can be built in a short period of

[1] A contribution of the Wildlife and Physiology Section of the Division of Fish and Wildlife. The authors wish to acknowledge the assistance of James E. Forbes of the U.S. Fish and Wildlife Service.

Figure 1. Head of adult (left) and juvenile (right) monk parakeet showing different color patterns. Arrow indicates tubercle on beak of juvenile.

Figure 2. Nest of monk parakeet from Glen Cove on Long Island. Nest was built around limb with long axis approximately horizontal as shown. This is typical position.

Figure 3. Eggs of monk parakeet.

time. A substantial nest (4 by 2 feet) that was torn down by the authors was, after a lapse of about 10 days, rebuilt in 2 weeks.

The largest nest encountered (Figure 2) was at Glen Cove on Long Island. It was 6 feet long by 4 feet deep with eight entrance tunnels 3 to 4 inches in diameter and a foot in depth. These tunnels opened toward the ground and served seven compartments, one compartment having two entrances. No outer chambers as described by Bump (1971) were present. This nest housed 13 parakeets some of which were building additions when the nest was discovered in August of 1973.

The eggs of the monk parakeet are chalk white. Two of those collected are illustrated in Figure 3. They measured 26 by 21 millimeters. In New York, the egg-laying period extends at least from April to July. The first nest inspected (on June 7, 1973 at Flushing on Long Island) contained 18 juveniles of various ages. The oldest was estimated to be 2 to 3 weeks old by comparison with the developmental photographs of closely related species given by Petrak (1969). Based on a 31-day incubation period (Rutgers and Norris, 1972), egg-laying would have begun in mid-April. In the nest that was rebuilt after being torn down, six eggs were laid during early July. At the nest at Glen Cove, seven 3-month-old juveniles and three pairs of adults were taken during the last week of July and the first week of August, and when the nest was removed on August 10 it was found to contain three viable eggs in one compartment, three non-viable eggs in another and two nestlings in a third. The latter situation suggests that some females may have more than one brood during the same season.

The fact that 62 per cent of the birds collected were juveniles is evidence that the monk parakeet is successfully reproducing in the New York metropolitan area. All the adult males taken were undergoing spermatogenesis as demonstrated by histological examination of the testes. Two (including the one at Troy) were bachelor nest builders, indicating that the presence of a female is not necessary either to stimulate spermatogenesis or to trigger the nest building impulse.

Recognizing the monk parakeet as an agricultural pest in its native range in South America, the U.S. Fish and Wildlife Service, various state conservation departments, state bird clubs and the Northeastern Association of State Departments of Agriculture have recommended prompt eradication or control of the species in the United States (Alden, 1973; Anonymous, 1973; Trimm, 1973). The

authors' observations of damage to fruit and ornamental trees and shrubs by this parakeet in the vicinity of its nests lend credence to the fear that it could become a serious agricultural pest here.

Because the nests are used for roosting as well as breeding, it is believed that the most effective control program would be to first locate the nests and then shoot or otherwise kill all free flying birds. The nest should be left intact until all the free-flying birds are shot or captured since it serves as a congregation point. The nest and all eggs and nestlings should then be destroyed. Shotgunning has proven effective in Argentina (Cano, 1963). Traps, mistnets and nest netting have been found inefficient, and live decoy birds have been only partially successful.

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Errata

In Table 4 (page 163) of the paper "Characteristics of a Small-lake Fishery as Determined by a Creel Census" by David M. Green (New York Fish and Game Jour. 19 (2) :155-167), the value for "catch per hour" for "all fish caught" should read 1.185 instead of 0.185.

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